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Estudo das diatomáceas bênticas em sistemas lóticos de Portugal Continental

Benthic diatoms in Portuguese watercourses

Volume 1

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Estudo das diatomáceas bênticas em sistemas lóticos de Portugal Continental

Resumo

A presente tese tem como objectivo aumentar o conhecimento da flora diatomológica de água doce de Portugal e inclui as seguintes partes: 1) uma compilação dos táxones citados para o país (Arquipélagos dos Açores e Madeira incluídos), baseada numa análise bibliográfica; 2) um atlas ilustrado em microscopia óptica e electrónica dos táxones mais frequentes e abundantes em Portugal Continental, baseado na análise de amostras de cursos de água e albufeiras de todo o país; 3) um estudo detalhado de dois grupos taxonomicamente problemáticos, como o complexo *Gomphonema tergestinum* - *G. rosenstockianum* e a descrição do *Achnanthidium caravelense*, uma nova espécie frequente e abundante no Norte de Portugal, em águas com concentração baixa a moderada de nutrientes; 4) a aplicação de métodos baseados em diatomáceas epilíticas litorais e índices diatomológicos (Índice de Poluosensibilidade Específica) na avaliação do estado ecológico de albufeiras, de acordo com os requisitos da Directiva Quadro da Água.

Palavras-chave: albufeiras, diatomáceas epilíticas, Directiva-Quadro da Água, morfologia, morfometria, Portugal, rios, ultraestrutura.

Número de palavras: 150

Benthic diatoms in Portuguese watercourses

Abstract

This thesis intends to increase the knowledge of the freshwater diatom flora from Portugal and comprises the following parts: 1) the compilation of the taxa already cited for the country (Azores and Madeira Archipelagos included) based on analysis of the literature; 2) the illustration under light and scanning electron microscopy of the most frequent and abundant taxa, based on samples collected in watercourses and reservoirs from the entire Continental Portugal; 3) a detailed study of two problematic species complexes, with taxonomic clarification of the *Gomphonema tergestinum* and *G. rosenstockianum* complex and description of *Achnanthidium caravelense*, a new taxon frequent and abundant in soft waters with low to moderate nutrient content in northern Portugal; 4) the application of methods based on epilithic littoral diatoms and diatom indices (Specific Polluosensitivity Index) for the assessment of the ecological status of reservoirs in accordance with the requirements of the Water Framework Directive.

Key-words: epilithic diatoms, morphology, morphometry, Portugal, reservoirs, ultrastructure. watercourses, Water Framework Directive.

Word Count: 148 words

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Chapter 1

GENERAL INTRODUCTION

1 General introduction

Diatoms are one of the most common algal groups in freshwaters as well as in marine ecosystems (ROUND et al. 1990; ARMBURST 2009). Several studies are being carried out in relation with their practical applications, namely in the frame of water quality evaluation, since they are being used in most European Union Member States (Portugal included) as cost-effective proxies for phytobenthos-based water quality assessment (INAG 2008; KELLY et al. 2009), and more recently as tracers of water source and hydrological connectivity (PFISTER et al. 2009). They are also subject of great interest nowadays, due to the present problematics related to some invasive diatom species (COSTE & ECTOR 2000) such as the "rock snot" *Didymosphenia geminata* (BELTRAMI et al. 2008; BLANCO & BÉCARES 2009; BLANCO & ECTOR 2009; WHITTON et al. 2009).

Management of aquatic ecosystems requires the development of both policy and technical infrastructures to meet the increasing challenges of the recent demands of water supply. In year 2000, through the implementation of the Water Framework Directive (WFD, Directive 2000/60/EC), the Council of the European Union advised European countries to assess running water quality by using diatoms, as part of the phytobenthos, in addition to other biological elements such as macrophytes, benthic invertebrate and fish fauna, due to their great value as bioindicators and because they represent a large part of the freshwater algal diversity (KING et al. 2000).

Diatoms are considered excellent environmental indicators because they occur in almost all aquatic habitats and react directly and sensitively to many physical, chemical and biological changes in river and stream ecosystems (STOERMER & SMOL 1999). Specifically, they have been shown to be effective indicators of pH, salinity and nutrients and have become one of the most widely used environmental indicators in relation to water quality problems such as water acidification, eutrophication, salinification and climate change (VAN DAM et al. 1994; ANDERSON 2000; TROBAJO PUJADAS 2007).

The use of benthic diatoms for biomonitoring purposes usually implies the application of diatom indices, calculated from relative abundance of diatom species. Until now, several different methods for indices calculation have been proposed and are routinely applied in European streams (ECTOR & RIMET 2005). Diatom indices are mainly based on the assignment of a pair of individual values (pollution sensitivity and stenoecy degree) to a certain set of common taxa summarized by LECOINTE et al. (1999). As these indices are based on diatom inventories from relatively homogeneous watercourses in Central and Western Europe, problems may arise when applied in other European regions (ROTT et al. 2003). One of these cases is the Mediterranean Region, due to the ecological particularities of its bioclimate and the specific hydrological pattern of the rivers, with great seasonal fluctuations (GOMÀ et al. 2004; BLANCO et al. 2008).

The current limitation on the use of diatom indices in the Mediterranean countries is also related to the poor knowledge of the freshwater diatom flora, since the works published until now are scarce, cover just small geographical areas, and consist mainly of floristic check-lists, without drawings or photos of key species and usually including the entire set of phytoplankton taxa, without a

particular focus on diatoms. Although there have been some valuable contributions, especially made by the researchers from the University of Aveiro who mainly published works focused on floristic, taxonomy, ecology, use of diatoms as bioindicators and on the impact of acid mine drainage on diatom communities (e.g. ALMEIDA 1998; ALMEIDA & GIL 2001; NUNES et al. 2003; LUÍS et al. 2009), nevertheless these works were mainly done in the central region of the country, but never in the entire territory of Portugal.

Lately, there is an urgent need to improve the knowledge on diatom communities in European countries, Portugal included, due to the transposition of the Water Framework Directive (WFD, Directive 2000/60/EC) to the Portuguese legislation in 2005 (Lei da Água, Lei n°58/2005; Decreto-Lei nº77/2006). Nevertheless, the use of diatoms to assess the ecological status of watercourses in Portugal is still in a preliminary phase, since there is not a deep knowledge about its freshwater diatom flora.

The present research aims to improve the knowledge about the specific variability between morphologically similar taxa, the biodiversity of benthic communities and species ecological preferences. In particular it refers to freshwater diatoms from rivers and reservoirs in Portugal, through the accomplishment of the following specific objectives: 1) to elaborate a catalogue of continental diatoms already cited from Portugal (including the Archipelagos of Azores and Madeira), with updated nomenclature, distribution and bibliography; 2) to elaborate a comprehensible iconographic guide (Atlas) with the most common freshwater diatom taxa occurring in the country, using light and scanning electron microscopy; 3) to study in detail the taxonomy and ecology of problematic species complexes, by combination of light and scanning electron microscopy; and 4) to verify the suitability of littoral epilithic diatoms in the assessment of the ecological status of reservoirs in the framework of the implementation of the WFD in the country. This research generally also intends to be useful for water managers in Portugal to easily identify and recognize diatoms, and therefore to use them more efficiently for bioindication purposes, accordingly to the recommendations of the Water Framework Directive (WFD, Directive 2000/60/EC).

Furthermore, since diatoms are generally considered to be cosmopolitans, the results can be applied in other Mediterranean and temperate countries and the increase of the knowledge about the morphology, ultrastructure and ecology of diatoms living in Portuguese watercourses and reservoirs can be also useful for water quality evaluation in regions with similar environmental conditions.

1.1 Innovation/originality

Although the study of diatoms in Portugal started at the middle of the XIXth century, the majority of the studies are floristic local lists, without any ecological information about the species and covering small geographic areas. Furthermore, the only recent studies with reference to the ecology of diatoms and related to their use in water quality assessment are mainly located in the central region of the country. Therefore, it is important to have information about the whole territory, since there are remarkable geological differences between the regions of Portugal, which influence the freshwater diatom communities. This research includes the study of the diatoms in all the ecoregions and hydrographical basins of Portugal, where we can also find temporary streams, mainly located in the south.

Apart from that, the vast majority of the existing works do not present any micrographs of the species mentioned. Therefore, it is useful to have detailed iconographical information about the species present in the country, since the floras that are currently being used are made for Central Europe and comprise a high number of species that are not present in Portugal, which can lead to identification difficulties. Consequently, this research can also provide a reference data basis for the monitoring works that will be developed within the Water Framework Directive (WFD, Directive 2000/60/EC) implementation in the country, due to the inclusion of a Catalogue with all the species already cited for the country and of the iconographic guide with micrographic material of the most common species present in freshwaters. In order to evaluate the ecological status of the watercourses of a region, by the application of diatom indices, there is a need to have a previous knowledge about their diatom flora. The innovation of this research also consists in the study of species complexes that are not well known, through the study of their taxonomy, ultrastructure, morphology, ecological preferences and biogeography, complementing the scarce available information.

Moreover, there are very few studies on the use of littoral epilithic diatoms for the evaluation of the ecological quality of reservoirs. This study represents a valuable contribution to validate the pre-established typology for Portugal and to analyse the ability of littoral epilithic diatoms to discriminate between reference and non-reference reservoirs.

1.2 Structure of the thesis

This thesis consists of 6 chapters, being chapter 1 a general introduction, chapters 2 to 5 publications already published, accepted or submitted to peer reviewed journals or monographs and chapter 6 the general conclusions:

Chapter 1. A general introduction with the background of the research, the main general and specific objectives of the study and its innovation and originality.

Chapter 2. A Catalogue with the freshwater diatom taxa already cited for the country, including the archipelagos of Madeira and Azores. This work consists essentially in the revision of

the information about freshwater diatoms available for the country, with a brief historical overview and detailed information about the updated nomenclatural and taxonomic synonyms and distribution of all the diatom taxa cited. Maps with the distribution of each taxon are also presented. It aims to be a useful publication to be consulted to clarify nomenclatural questions and to check distribution and species records for the country. Due to the enormous number of pages (1859), this work is only partially presented in the paper version of the thesis, consisting only in the introductory part, the complete information is presented as an example for a few taxa and finally the complete list of diatom taxa cited for the country (with the most recent synonyms) is also supplied. The complete version with the text of this catalogue is included in the electronic version.

Chapter 3. An iconographic atlas that intends to serve as a useful tool for the identification of common diatom taxa in the country. It is based in taxa inventoried from 363 sampling sites in watercourses covering the whole hydrographic basins and from 18 reservoirs seasonally sampled by the team of the project of the National Water Institute (INAG) in 2006. Each of the 295 taxa is generally illustrated by means of a series of light micrographs to show the whole range of the morphological variability of each taxon; furthermore, scanning electron micrographs are also presented for the taxa that pose identification difficulties or are somehow particularly interesting. For some of the taxa different populations from several sampling sites are provided, in order to better illustrate their morphological variability. The morphometric measurements of the populations illustrated are provided for all the taxa presented in the atlas and the new records for the Iberian Peninsula are also characterized in terms of ecological preferences for several environmental parameters. Due to the huge number of pages with the micrographs, the part of this chapter that is constituted by the taxa characterization and the light and scanning electron micrographs is presented separately in the second volume of the thesis.

Chapter 4. This chapter consists of the detailed taxonomical study of two species complexes common in Portugal, and is formed by two separate papers, one already published and the other in press, in international peer reviewed journals. The subject is briefly introduced, with remarks to the recent issues related to the increase in the number of new species described, the boundaries of the species concept in diatoms and the relation of the number of species described to the improvement of the techniques applied. Afterwards the two species complexes (*Gomphonema rosenstockianum* and *G. tergestinum* and *Achnanthidium minutissimum*) are presented in detail. In one of the papers a new *Achnanthidium* species frequent and abundant in the north of the country is formally described.

Chapter 5. This chapter consists of a paper submitted to an international peer reviewed journal. It aims to validate the established typology for Portugal, to analyse the ability of littoral

epilithic diatoms to discriminate between reference and non-reference reservoirs, in the framework of the application of the Water Framework Directive (WFD, Directive 2000/60/EC) in the country.

Chapter 6. This final chapter includes the general conclusions of the work, summarizes the main results and presents the perspectives for further research on the subject.

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Chapter 2

CATALOGUE OF CONTINENTAL DIATOMS FROM PORTUGAL, INCLUDING THE ARCHIPELAGOS OF AZORES AND MADEIRA: UPDATED NOMENCLATURE, DISTRIBUTION AND BIBLIOGRAPHY

In preparation to *Diatom Monographs* as:

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2 Catalogue of continental diatoms from Portugal, including the Archipelagos of Azores and Madeira: updated nomenclature, distribution and bibliography

Abstract

This catalogue aims to compile the information available on continental (recent and fossil) diatoms in Portugal, including the Archipelagos of Madeira and Azores, since the early beginnings of the diatom studies in Portugal at the middle of the XIXth century until 2010.

The diatom taxa are presented following an updated taxonomy; nevertheless, in order to provide a historical overview, the nomenclatural synonyms found in the literature from Portugal are also included. For all the 1381 taxa the following information is presented: basionym, nomenclatural synonyms, citations (with the precise indication of the sampling sites), frequent taxonomical synonyms and a distribution map.

Resumo

Este catálogo tem como objectivo compilar a informação disponível sobre diatomáceas continentais (recentes e fósseis) de Portugal, incluindo os Arquipélagos da Madeira e dos Açores, desde que se iniciaram estes estudos em meados do século XIX até 2010.

Os táxones de diatomáceas são ordenados alfabeticamente e seguindo uma taxonomia actualizada, apesar de serem incluídos também os sinónimos nomenclaturais e taxonómicos mencionados na literatura consultada sobre Portugal. Para todos os 1381 táxones é apresentada a seguinte informação: basiónimo, sinónimos nomenclaturais, citações (com indicação exacta do local de amostragem), sinónimos taxonómicos mais comuns e um mapa de distribuição a nível de concelho.

2.1 Introduction

2.1.1 Objective and scope of this catalogue

This catalogue aims to compile the information available regarding the knowledge on continental (recent and fossil) diatoms in Portugal, including the Archipelagos of Azores and Madeira. It comprises information from diatom studies since the early beginnings of this subject in Portugal at the middle of the XIXth century until 2010.

Only non-marine diatoms were taken into account; therefore, only information regarding streams, rivers, fountains, sources, reservoirs, lakes, lagoons, ponds and upper reaches of estuaries, where freshwater diatoms can be found, was included.

In this catalogue all kinds of diatom studies were considered, including reports, scientific papers, PhD thesis and post-doc studies. Works such as degree and master dissertations were excluded, due to the uncertainty of the identifications provided.

Although some of the information has already been presented in ABOAL et al. (2003) about Mainland Portugal inside the Iberian Peninsula, we aimed to provide, whenever possible, the most precise information about the sampling site, as well as the information regarding the Archipelagos of Azores and Madeira. In addition, the known distribution of each taxon is documented by maps. Furthermore, more than 120 additional references were included in this work.

2.1.2 Regions and subregions of Portugal

The ordination of the territory, according to the Nomenclature of Territorial Units for Statistics (NUTS), divides Portugal in the three units I, II and III. The first subdivision of Portugal (NUTS I) separates Mainland Portugal from the two autonomous regions of the Azores and Madeira Archipelagos. The second subdivision of Portugal (NUTS II) divides the country into five regions, administered by the Commissions for Coordination and Regional Development (Comissões de Cooperação e Desenvolvimento Regional) in mainland Portugal, plus the two autonomous regions that correspond to NUTS II regions. These 7 regions are subdivided into 30 subregions (NUTS III). All regions (from the north to the south) with the respective subregions are listed alphabetically below, the numbers correspond to the codes presented in the Figure 2.2.

1) REGION: NORTE
- Alto Trás-os-Montes (1)
- Ave (2)
- Cávado (3)
- Douro (4)
- Entre Douro e Vouga (5)
- Grande Porto (6)
- Minho-Lima (7)
- Tâmega (8)

2) REGION: CENTRO
- Baixo Mondego (9)
- Baixo Vouga (10)
- Beira Interior Norte (11)
- Beira Interior Sul (12)
- Cova da Beira (13)
- Dão-Lafões (14)
- Médio Tejo (15)
- Oeste (16)
- Pinhal Interior Norte (17)
- Pinhal Interior Sul (18)
- Pinhal Litoral (19)
- Serra da Estrela (20)

3) REGION: LISBOA
- Grande Lisboa (21)
- Península de Setúbal (22)

4) REGION: ALENTEJO
- Alentejo Central (23)
- Alentejo Litoral (24)
- Alto Alentejo (25)
- Baixo Alentejo (26)
- Lezíria do Tejo (27)

5) REGION: ALGARVE
- Algarve (28)

6) REGION: AUTONOMOUS REGION OF AZORES
- Autonomous Region of Azores (29)

7) REGION: AUTONOMOUS REGION OF MADEIRA
- Autonomous Region of Madeira (30)

The maps with the location of Mainland Portugal and the Archipelagos of Madeira and Azores, including the regions and subregions of the country, are presented in Figure 2.21 and Figure 2.2.

.

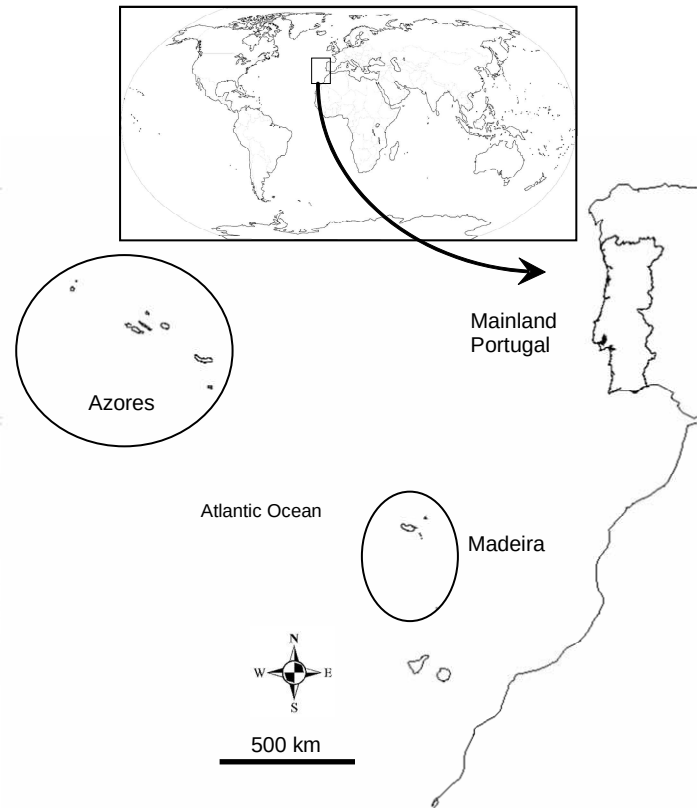

Figure 2.1 Location of Mainland Portugal and the Archipelagos of Azores and Madeira.

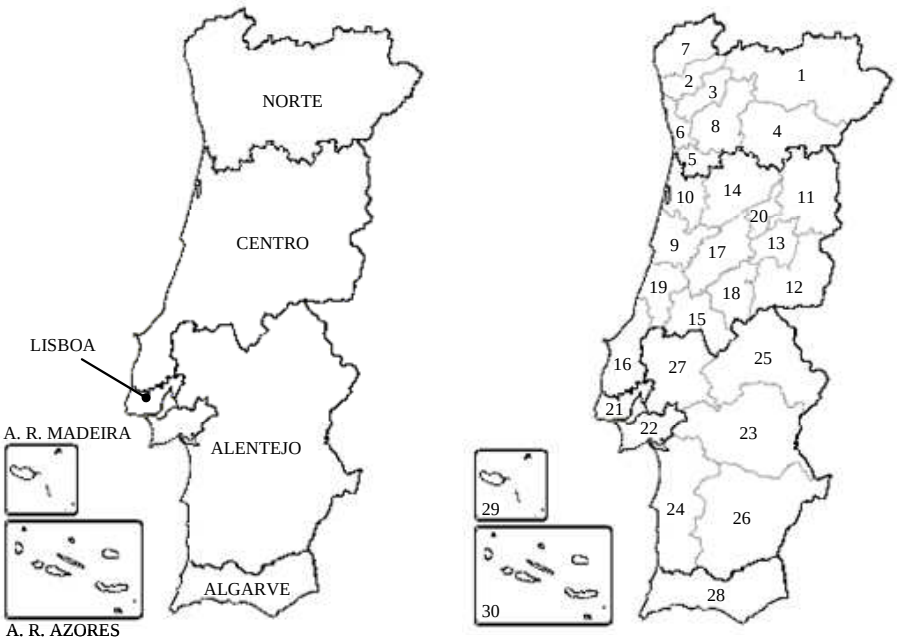

Figure 2.2 Regions (A) and subregions (B) of Portugal. See number codes in the text.

2.1.3 Historic overview

2.1.3.1 Mainland Portugal

To our knowledge, the first records of freshwater diatoms from Portugal have been published by EHRENBERG in 1845 and consist in few diatoms identified from material collected in the riverbanks of Tejo River. Afterwards, COLMEIRO in 1867 and 1869 also mentioned a few diatom species collected in Coimbra and Porto in his major work including the whole Iberian Peninsula.

Therefore, the first studies considering only Portugal have started at the end of the XIXth century, due to the initiatives promoted by Dr. JÚLIO HENRIQUES, at that time director of the Botanical Garden of Coimbra and of the Sociedade Broteriana. The latter is a Society created in honour of BROTERO (a notable Portuguese botanist) that still exists nowadays and produces the Boletim da Sociedade Broteriana. It has first been published in 1880 and has embraced the first published studies on diatoms in Portugal.

The Sociedade Broteriana promoted phycological studies at the turn of the XIXth century by encouraging the collection and interchange of botanical specimens that were later identified by international experts as HAUCK and KÜTZING (SANTOS et al. 2002). Most of these diatoms were collected by MÖLLER (supervisor of the Coimbra Botanical Garden at that time) and by NEWTON (administrator of the Sociedade de Instrução do Porto).

At the beginning of the XXth century, several important contributions to the knowledge of diatoms in Portugal were made. ZIMMERMANN, for example, published the *Catálogo das Diatomáceas Portuguesas* subdivided in several Centurias (ZIMMERMANN 1906, 1909b, 1910, 1914), as well as the *Algumas diatomáceas novas ou curiosas* (ZIMMERMANN 1915a, 1917). At that time, the studies were mainly taxonomical and the sampling was indiscriminately performed in every type of substrate or water body by the researcher, his friends or collaborators. FAUSTO LOPO DE CARVALHO published a more detailed study about the *Diatomáceas da Guarda* (CARVALHO 1913), with samples collected in rivers, sources and fountains in the central region of Portugal.

In the middle of the XXth century, ALFREDO ANDRADE SILVA, working at the Botany Institute Dr. GONÇALO SAMPAIO (University of Porto) also significantly contributed to the knowledge of diatoms in the country. His works included the study of fossil and recent freshwater diatoms collected in Rio Maior, Alpiarça and Óbidos deposits (SILVA 1945, 1946b), Serra do Gerês (SILVA 1950a), and Porto (SILVA 1950b).

Afterwards, in the beginning of the second half of the XXth century several studies on algae were made, although not only focused on diatoms, but including the total phytoplankton. ARNOLD NAUWERCK published the results about a survey of planktonic algae, including diatoms, from several reservoirs from the whole country (NAUWERCK 1959, 1962). MARIA DO ROSÁRIO OLIVEIRA followed this trend, publishing several studies about phytoplankton in different rivers and reservoirs from the whole country (Azores included). There was not any particular attention given to diatoms although this group is present in the floristic lists presented (OLIVEIRA 1971a, b, 1975, 1976, 1981, 1982a,b,c, 1984a,b,c, 1985, 1987, 1989, 1991, 1992, 1996; OLIVEIRA & CALDAS 1970, 1971;

OLIVEIRA et al. 1985; OLIVEIRA et al. 1989; OLIVEIRA & COUTINHO 1992; OLIVEIRA & MONTEIRO 1992, 1993a,b, 1995).

Since the end of the XXth century, due to contributions by the researchers from the University of Aveiro, several works about the freshwater diatoms of the central region of Portugal have been published (ALMEIDA 1998, 2001; ALMEIDA & GIL 2000, 2001; GIL 1988, 1989, 1993; GIL et al. 1989-1990, 1991; GIL & ALMEIDA 1993; NUNES 2007; NUNES et al. 2002, 2003; RINO & GIL 1989). These works are focused not only on floristic and taxonomy, but also on ecology and the use of diatoms as bioindicators.

The evolution of the number of studies and their annual accumulation from 1845 to 2010 made in Mainland Portugal is graphically represented in Figure 2.3 and Figure 2.4, respectively. Furthermore, the increase of total taxa cited for the country is presented in Figure 2.5.

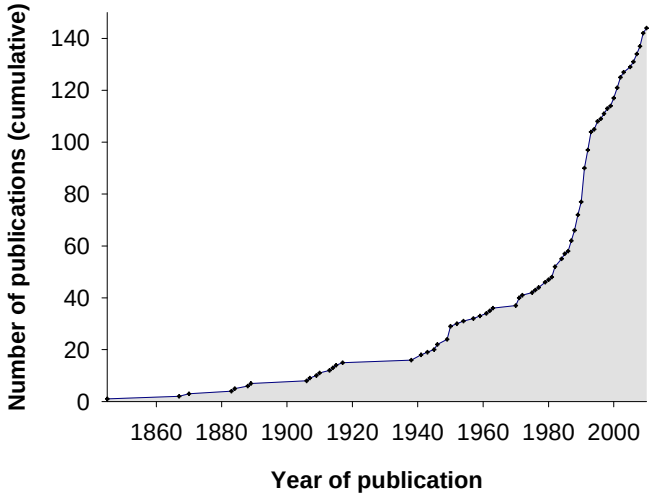

Figure 2.3 Evolution of the number of publications with diatoms for Mainland Portugal.

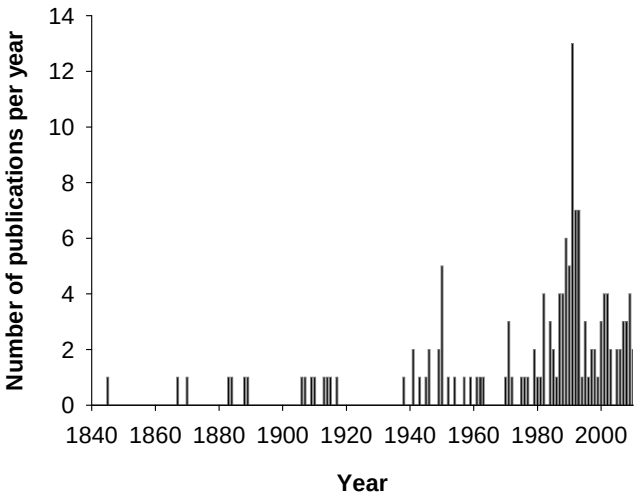

Figure 2.4 Number of publications with diatoms for Mainland Portugal per year.

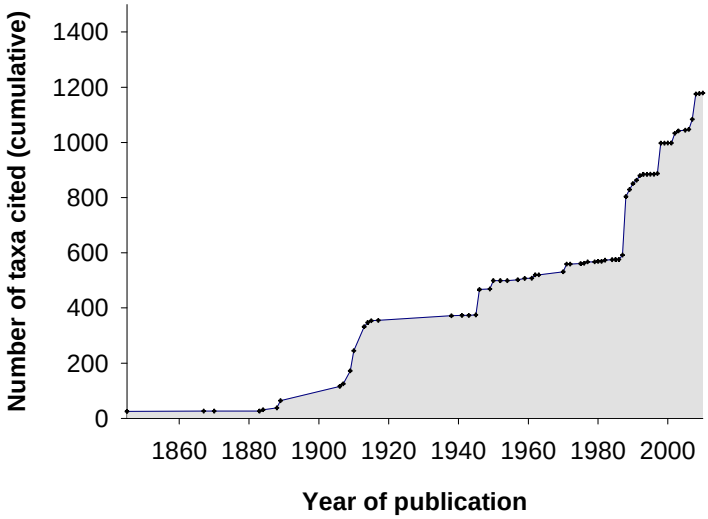

Figure 2.5 Evolution of the total number of diatom taxa cited for Mainland Portugal.

2.1.3.2 Madeira and Azores Archipelagos

As regards the Madeira Archipelago, very few references about diatoms exist. The first works known date back to the beginning of the XXth century. These studies were mainly realized by ZIMMERMANN (1909a, 1910-1911). However, some references about diatoms from the Madeira Archipelago can also be found in the compilation made by TEMPÈRE & PERAGALLO (1907-1915). Later, SCHODDUYIN (1927) published his *Contribution pour l'hydrobiologie des Îles de Funchal et Porto Santo*, based on samples collected by CARLOS MENEZES. Subsequently, MÖLDER (1947) also mentioned some freshwater diatom species from Madeira in his work about algae from the Azores. In the last decades, no reports about freshwater algae from this Archipelago have been published. Consequently, only a few diatom records are available from this period, presented in general books, such as KRAMMER & LANGE-BERTALOT (1986, 1991b).

The Azores Archipelago has become an area of scientific interest at the end of the XIXth century, when several renowned North American and European naturalists visited the Archipelago during their scientific expeditions. Nevertheless, the majority of these pioneering works were limited in scope and only included few species of freshwater algae (e.g. ARCHER 1874; MOSELEY 1874; O'MEARA 1874), excepting the work of HOLMBOE (1901), which was the first deep study of the freshwater diatoms of the archipelago. In the decades of 1930 and 1940, more exhaustive studies were published, such as those of KRIEGER (1931), MANGUIN (1942), BOURRELLY & MANGUIN (1946a, 1946b) and MÖLDER (1947). More recently, a number of works were published from expeditions of University of Azores researchers to several islands (GONÇALVES 1996; AZEVEDO et al. 2005; GONÇALVES 2008). Nevertheless, it is important to mention that the majority of the available works obviously refer to the natural lakes, which are the most important and emblematic freshwater

resources of the Archipelago (OLIVEIRA 1989; GONÇALVES 1996, 1997; GONÇALVES & RODRIGUES 1999; GONÇALVES 2008). Recently a compilation of the diatoms cited for the Archipelago has been published and these results are also here included (GONÇALVES et al. 2010). The evolution in publications number including diatoms from the Azores Archipelago is graphically represented in Figure 2.6. Furthermore, the increase of total diatom taxa cited for the archipelago is presented in Figure 2.7.

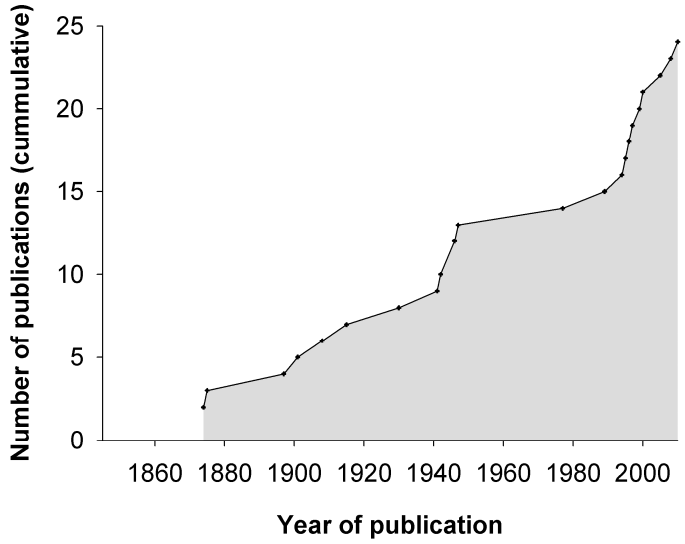

Figure 2.6 Evolution of the number of publications with diatoms for the Azores Archipelago.

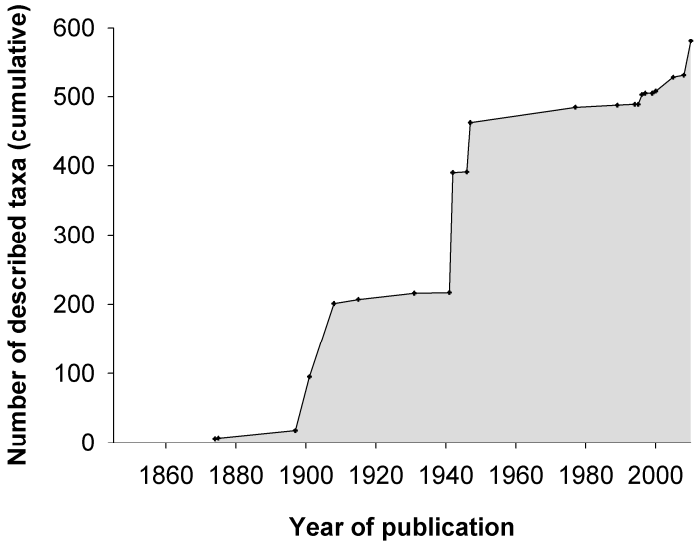

Figure 2.7 Evolution of the total number of diatom taxa cited for the Azores Archipelago.

2.1.4 Geographic overview

To provide information about the geographic areas that have been deeper studied regarding diatoms, a map with the number of records for each municipality is presented in Figure 2.8. From the analysis of the map is evident that more than 50% of the territory is still unexplored, which shows the lack of studies about diatoms in the country. Despite of the efforts done within the implementation of the Water Framework Directive in Portugal, which covered the entire territory, these results are not observable here. Until now, the only published work with these results for the whole country is INAG (2008), which is a sampling protocol without indication on the distribution of the species.

This lack of diatom studies in the country can be seen in the distribution maps for each species. Therefore, the fact that some species present a more restrict distribution doesn't always mean that they are not present in other regions, but also that there are no studies done in those areas.

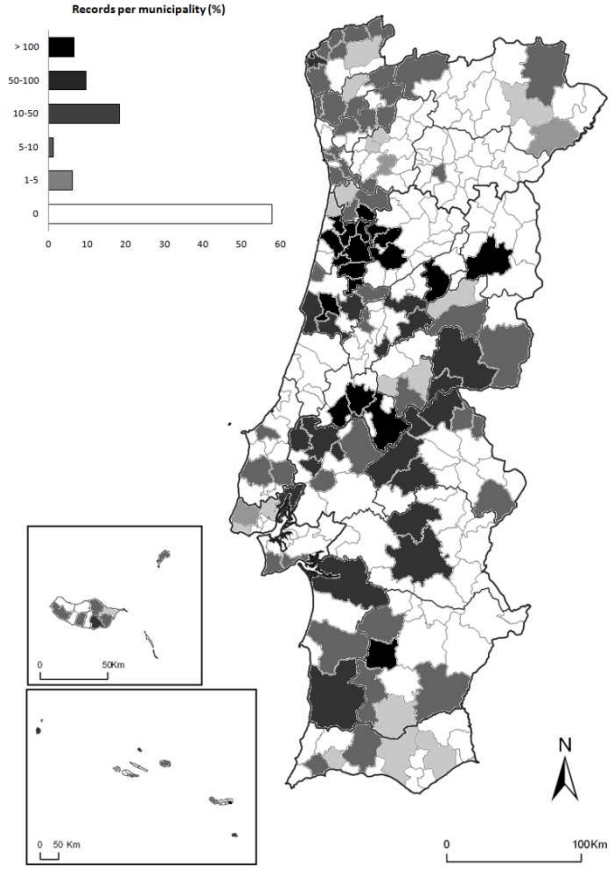

Figure 2.8 Number of records per municipality (%).

2.2 Catalogue

The total number of taxa listed in this catalogue is of 1381, compiled from the 173 publications considered. For the accepted diatom names, the information provided in the Catalogue of Diatom Names by the California Academy of Sciences is followed (http://research.calacademy.org/research/diatoms/names/). This aims to avoid the repetition of taxa under different synonyms. In addition to these names, the **basionym** and the **nomenclatural synonyms** mentioned in the publications checked are provided. Nevertheless, to avoid the loss of important information and to allow also an historical overview, the literal name used for each species in the original publication is placed after the authors of the publication. The **taxonomical synonyms** are presented according to the most common bibliographic references, such as KRAMMER & LANGE-BERTALOT (1986, 1988, 1991a,b) and KRAMMER (1997a,b, 2000). Nevertheless these synonyms are kept separately, since there is still a need of further studies to confirm the validity of this synonymy.

The taxa are listed alphabetically rather than following a systematic ordination in order to facilitate the search, especially due to the huge number of pages.

Each taxon is presented, whenever possible, by the exact sampling site mentioned in the literature. The information about the **distribution** of each species follows the following scheme:

REGION
Subregion
    Municipality (District)
        Site
            Reference

The information about the District is also included, because it is still a well-known and easily recognizable geographical division in Portugal. Each site also refers to the watercourse and the main hydrographical basin to which it belongs to ease the understanding of the information provided, and moreover because this information can be useful for the main international basins, as Tejo/Tajo, Douro/Duero, Minho/Miño, Lima/Limia, Tâmega/Támega and Guadiana.

Maps with the municipalities where each taxon has been cited, showing the geographical distribution of each taxon in Mainland Portugal and the Madeira and Azores Archipelagos, are included in a separate volume and their respective figure numbers are presented together with the Distribution.

Due to the enormous number of pages that constitute the complete version, are hereby presented only the distribution and maps for four taxa. Nevertheless, in order to provide the most of the information possible, in spite of the practical size limitations all the checked references from Portugal are provided as well as the complete list of the taxa already cited for the country. The version with the complete text of this catalogue is provided in the electronic version of the thesis.

***Achnanthes* BORY 1822**, p. 79, 593 (vol. 1)
[CAS ref. 000145]

***Achnanthes brevipes* C. AGARDH 1824**, p. 1 [CAS ref. 000102]

Distribution (Figure 2.9):

REGION: ALENTEJO

Subregion: Lezíria do Tejo

Municipality: Santarém (District: Santarém)

Site: Ómnias, Tejo River (Tejo Basin)

Reference: BRITO & ANDRADE 1992 (as *Achnanthes brevipes*)

***Achnanthes brevipes* var. *intermedia* (KÜTZING) CLEVE 1895**, p. 193 [CAS ref. 000949]

Basionym: *Achnanthes intermedia* KÜTZING 1833 [CAS ref. 000594]

Distribution (Figure 2.10):

REGION: NORTE

Subregion: Grande Porto

Municipality: Porto (District: Porto)

Site: Not Specified

Reference: COLMEIRO 1889 (as *Achnanthes intermedia* KG.)

***Achnanthes brevipes* var. *minor* H. PERAGALLO in H. PERAGALLO & PERAGALLO 1897**, pl. 1, fig. 16-18 [CAS ref. 001052]

Distribution (Figure 2.11):

REGION: NORTE

Subregion: Minho-Lima

Municipality: Viana do Castelo (District: Viana do Castelo)

Site: Viana do Castelo

Reference: ZIMMERMANN 1910 (as *Achnanthes brevipes* AG. var. *minor* PER.)

***Achnanthes coarctata* (BRÉBISSON ex W. SMITH) GRUNOW in CLEVE & GRUNOW 1880**, p. 20 [CAS ref. 000241]

Basionym: *Achnanthidium coarctatum* BRÉBISSON ex W. SMITH 1855 [CAS ref. 000864]

Distribution (Figure 2.12):

REGION: NORTE

Subregion: Grande Porto

Municipality: Matosinhos (District: Porto)

Site: Not Specified

Reference: ZIMMERMANN 1910 (as *Achnanthes coarctata* (BRÉB.) GRUN.)

REGION: CENTRO

Subregion: Baixo Mondego

Municipality: Montemor-o-Velho (District: Coimbra)

Site: Marsh near Montemor-o-Velho

Reference: Santos et al. 2002 (as *Achnanthes coartacta* (BRÉBISSON) GRUNOW)

Subregion: Baixo Vouga

Municipality: Águeda (District: Aveiro)

Site: Agadão, Agadão River (Vouga Basin)

Reference: Gil 1988 (as *Achnanthes coarctata* BRÉBISSON)

Site: Avelal de Baixo, Águeda River (Vouga Basin)

Reference: Gil 1988 (as *Achnanthes coarctata* BRÉBISSON)

Site: Castanheira do Vouga, confluence of Agadão and Águeda Rivers (Vouga Basin)

References: GIL 1988 (as *Achnanthes coarctata* BRÉBISSON); GIL et al. 1989-90 (as *Achnanthes coarctata*)

Site: Ponte dos Diabos, Alfusqueiro River (Vouga Basin)

Reference: GIL 1988 (as *Achnanthes coarctata* BRÉBISSON)

Site: Raivo, Águeda River (Vouga Basin)

Reference: GIL 1988 (as *Achnanthes coarctata* Brébisson)

Site: Ribeiro, Alfusqueiro River (Vouga Basin)

Reference: GIL 1988 (as *Achnanthes coarctata* Brébisson)

Municipality: Anadia (District: Aveiro)

Site: São João da Azenha, Cértima River (Vouga Basin)

Reference: RINO & GIL 1989 (as *Achnanthes coarctata*)

Site: Tamengos, Cértima River (Vouga Basin)

Reference: RINO & GIL 1989 (as *Achnanthes coarctata*)

Municipality: Aveiro (District: Aveiro)

Site: Aveiro, lake in the municipal park (artificial substrate)

Reference: GIL & ALMEIDA 1993 (as *Achnanthes coarctata* DE BRÉBISSON)

Site: Requeixo, Cértima River (Vouga Basin)

Reference: ALMEIDA 1998 (as *Achnanthes coarctata* (BRÉBISSON) GRUNOW)

Site: Requeixo 1, Águeda River, upstream of the confluence with Cértima River (Vouga Basin)

Reference: GIL 1988 (as *Achnanthes coarctata* BRÉBISSON)

Site: Requeixo 2, Águeda River, downstream of the confluence with Cértima River (Vouga Basin)

Reference: GIL 1988 (as *Achnanthes coarctata* BRÉBISSON)

Municipality: Oliveira do Bairro (District: Aveiro)

Site: Canha, Casal Estevão, Cértima River (Vouga Basin)

Reference: RINO & GIL 1989 (as *Achnanthes coarctata*)

Site: Perrães, Levira River (Vouga Basin)

Reference: ALMEIDA 1998 (as *Achnanthes coarctata* (BRÉBISSON) GRUNOW)

Site: Repolão, Cértima River (Vouga Basin)

Reference: RINO & GIL 1989 (as *Achnanthes coarctata*)

Subregion: Beira Interior Norte

Municipality: Guarda (District: Guarda)

Site: Mondego River (Mondego Basin)

References: Carvalho 1913 (as Achnanthes coarctata (Bréb.) Grun.); Santos & Carvalho 2001 (as Achnanthes coarctata (Bréb.) Grun.)

Site: Vila Patrício

Reference: Carvalho 1913 (as *Achnanthes coarctata* (BRÉB.) GRUN.)

Subregion: Dão-Lafões

Municipality: Oliveira de Frades (District: Viseu)

Site: Destriz, Alfusqueiro River (Vouga Basin)

Reference: GIL 1988 (as *Achnanthes coarctata* BRÉBISSON)

Site: São João do Monte, Águeda River (Vouga Basin)

Reference: GIL 1988 (as *Achnanthes coarctata* BRÉBISSON)

Municipality: Tondela (District: Viseu)

Site: Boi, Agadão River (Vouga Basin)

Reference: GIL 1988 (as *Achnanthes coarctata* BRÉBISSON)

Site: In the proximity of Tondela, Criz River (Mondego Basin)

Reference: SANTOS et al. 2002 (as *Achnanthes coarctata* (BRÉBISSON) GRUNOW)

Municipality: Vouzela (District: Viseu)

Site: Cambra, Alfusqueiro River (Vouga Basin)

Reference: GIL 1988 (as *Achnanthes coarctata* BRÉBISSON)

Site: Ponte da Várzea, Alfusqueiro River (Vouga Basin)

Reference: GIL 1988 (as *Achnanthes coarctata* BRÉBISSON)

Subregion: Médio Tejo

Municipality: Torres Novas (District: Santarém)

Site: Renova, Almonda River (Tejo Basin)

Reference: OLIVEIRA & CALDAS 1971 (as *Achnanthes coarctata* (BREB.) GRUN.)

Subregion: Pinhal Interior Norte

Municipality: Pampilhosa da Serra (District: Coimbra)

Site: Alto Ceira Reservoir, Ceira River (Mondego Basin)

Reference: SANTOS et al. 2002 (as *Achnanthes coartacta* (BRÉBISSON) GRUNOW)

Subregion: Serra da Estrela

Municipality: Seia (District: Guarda)

Site: Sabugueiro, Vale do Rossim Reservoir

Reference: SANTOS et al. 2002 (as *Achnanthes coartacta* (BRÉBISSON) GRUNOW)

Subregion: Not Specified

Municipality: Not Specified

Site: Not Specified

Reference: GIL et al. 1991 (as *Achnanthes coarctata*)

REGION: LISBOA

Subregion: Península de Setúbal

Municipality: Setúbal (District: Setúbal)

Site: Comenda

Reference: ZIMMERMANN 1910 (as *Achnanthes coarctata* (BRÉB.) GRUN.)

REGION: AUTONOMOUS REGION OF AZORES

Municipality: Povoação (São Miguel Island)

Site: Lagoa das Furnas

Reference: Chaves 1908 (as *Achnanthes coarctata* BRÉB.)

Municipality: Santa Cruz da Graciosa (Graciosa Island)

Site: Barreiro

Reference: AZEVEDO et al. 2005 (as *Achnanthes coarctata*)

REGION: AUTONOMOUS REGION OF MADEIRA

Municipality: Porto Santo (Porto Santo Island)

Site: Ponte do Espírito Santo

Reference: ZIMMERMANN 1910-1911 (as *Achnanthes coarctata* (BRÉB.) GRUN.)

Municipality: Santa Cruz (Madeira Island)

Site: Fonte do Mestre Henrique, Caniço

Reference: ZIMMERMANN 1909a (as *Achnanthes coarctata* (BRÉB.) GRUN.)

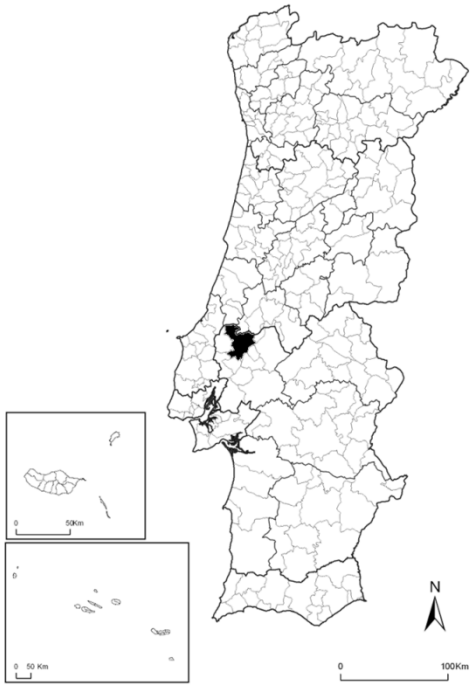

Figure 2.9 Distribution map of *Achnanthes brevipes*

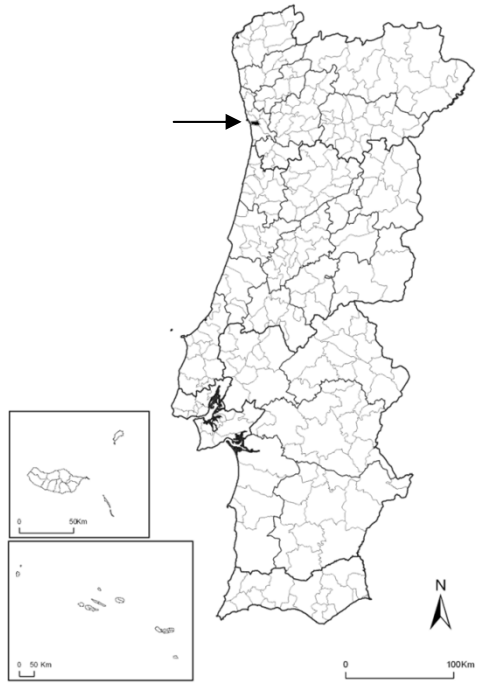

Figure 2.10 Distribution map of *Achnanthes brevipes* var. *intermedia*

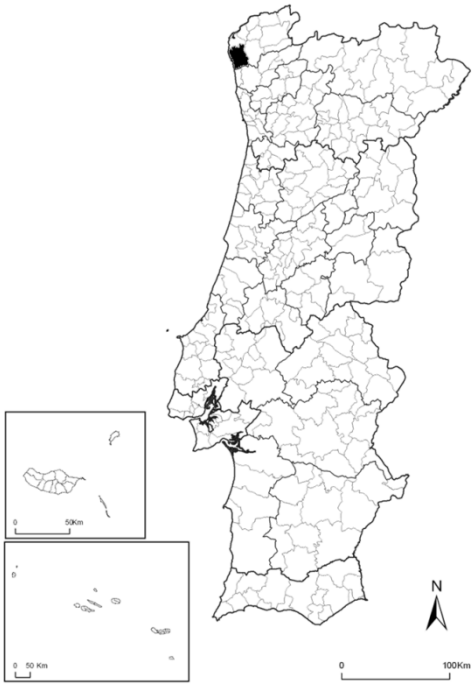

Figure 2.11 Distribution map of *Achnanthes brevipes* var. *minor*

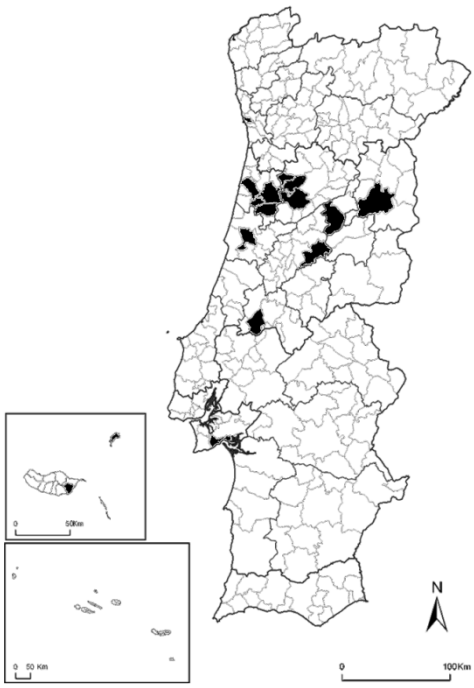

Figure 2.12 Distribution map of *Achnanthes coarctata*

2.3 Taxa list

The list with all the taxa already cited for the country is hereby presented. Only the updated names mentioned in the literature from the country are presented, since the inclusion of all nomenclatural synonyms and basionyms would highly increase the length of this list.

ACANTHOCERAS Honigmann 1910
Acanthoceras zachariasii (Brun) Simonsen 1979
ACHNANTHES Bory 1822
Achnanthes andicola (Cleve) Hustedt 1911
Achnanthes brevipes C. Agardh 1824
Achnanthes brevipes* var. *intermedia (Kützing) Cleve 1895
Achnanthes brevipes* var. *minor H. Peragallo 1897
Achnanthes coarctata (Brébisson ex W. Smith) Grunow in Cleve & Grunow 1880
Achnanthes coarctata* var. *elliptica Krasske 1929
Achnanthes conspicua* var. *brevistriata Hustedt 1930
Achnanthes crucifera Østrup 1910
Achnanthes elata (Leuduger-Fortmorel) H.P. Gandhi 1960
Achnanthes exigua* var. *elliptica Hustedt 1937
Achnanthes gibberula Grunow in Cleve & Grunow 1880
Achnanthes grimmei Krasske 1925
Achnanthes inflata (Kützing) Grunow 1867
Achnanthes lanceolata* var. *capitata O. Müller 1909
Achnanthes lanceolata* var. *omissa Reimer in Patrick & Reimer 1966
Achnanthes lanceolata* var. *ventricosa Hustedt 1914
Achnanthes longipes C. Agardh 1824
Achnanthes longipes* f. *lata C. Zimmermann 1910
Achnanthes minima Carter 1961
Achnanthes minutissima* var. *cryptocephala Grunow in Van Heurck 1880
Achnanthes minutissima* var. *jackii (Rabenhorst) Lange-Bertalot & Ruppel 1980
Achnanthes parvula Kützing 1844
Achnanthes rupestoides M.H. Hohn 1961
Achnanthes saxonica Krasske in Hustedt 1933
Achnanthes sphacelata J.R. Carter 1970
Achnanthes subsessilis Kützing 1833
***ACHNANTHIDIUM* Kützing 1844**
Achnanthidium biasolettianum (Grunow in Cleve & Grunow) Lange-Bertalot 1999
Achnanthidium bioretii (H. Germain) O. Monnier, Lange-Bertalot & Ector 2007
Achnanthidium catenatum (J. Bílý & Marvan) Lange-Bertalot 1999
Achnanthidium exiguum (Grunow) Czarnecki 1994
Achnanthidium exiguum* var. *constrictum (Grunow) N.A. Andresen, Stoermer & R.G. Kreis, Jr. 2000
Achnanthidium exiguum* var. *heterovalvum (Krasske) Czarnecki 19940
Achnanthidium exile (Kützing) Round & Bukhtiyarova 1996
Achnanthidium gracillimum (F. Meister) Lange-Bertalot in Krammer & Lange-Bertalot 2004
Achnanthidium helveticum (Hustedt) O. Monnier, Lange-Bertalot & Ector 2007
Achnanthidium lineare W. Smith 1855
Achnanthidium macrocephalum (Hustedt) Round & Bukhtiyarova 1996
Achnanthidium minutissimum (Kützing) Czarnecki 1994
Achnanthidium minutissimum* f. *inconspicuum (Østrup) Compère & Riaux-Gobin 2009
Achnanthidium minutissimum* var. *affinis (Grunow) Bukhtiyarova 1995
Achnanthidium rosenstockii (Lange-Bertalot) Lange-Bertalot in Krammer & Lange-Bertalot 2004
Achnanthidium saprophilum (H. Kobayasi & Mayama) Round & Bukhtiyarova 1996
Achnanthidium subatomus (Hustedt) Lange-Bertalot 1999a
Achnanthidium subhudsonis (Hustedt) H. Kobayasi in Kobayasi et al. 2006
ACTINOCYCLUS Ehrenberg 1837
Actinocyclus normanii (W. Gregory ex Greville) Hustedt 1957
Actinocyclus subtilis (W. Gregory) Ralfs in Pritchard 1861
ACTINOPTYCHUS Ehrenberg 1843
Actinoptychus undulatus (Kützing) Ralfs in Pritchard 1861
ADLAFIA Gerd Moser, Lange-Bertalot & Metzeltin 1998
Adlafia bryophila (J.B. Petersen) Gerd Moser, Lange-Bertalot & Metzeltin 1998
Adlafia minuscula (Grunow) Lange-Bertalot in Lange-Bertalot & Genkal 1999
Adlafia minuscula var. ***muralis*** (Grunow) Lange-Bertalot in Lange-Bertalot & Genkal 1999
AMPHIPLEURA Kützing 1844
Amphipleura kriegeriana (Krasske) Hustedt 1954
Amphipleura lindheimeri Grunow 1862
Amphipleura pellucida (Kützing) Kützing 1844
AMPHORA Ehrenberg ex Kützing 1844
Amphora birugula M.H. Hohn 1961
Amphora coffeaeformis* var. *acutiuscula (Kützing) Hustedt 1930
Amphora copulata (Kützing) Schoeman & R.E.M. Archibald 1986
Amphora delicatissima Krasske in Hustedt 1930

Amphora dubia W. Gregory 1857
Amphora exigua W. Gregory 1857
Amphora fogediana Krammer in Krammer & Lange-Bertalot 1985
Amphora inariensis Krammer 1980
Amphora libyca Ehrenberg 1840
Amphora lineolata Ehrenberg 1838
Amphora ovalis (Kützing) Kützing 1844
Amphora ovalis* f. *minor (Grunow in Van Heurck) Van Heurck 1885
Amphora ovalis* var. *affinis (Kützing) Pero 1893
Amphora ovalis* var. *gracilis (Ehrenberg) Van Heurck 1885
Amphora ovalis* var. *minor Rabenhorst 1864
Amphora pediculus (Kützing) Grunow in Schmidt 1875
Amphora perpusilla Grunow 1884
Anaulus Ehrenberg 1844
Anaulus balticus Simonsen 1959
Aneumastus D.G. Mann & Stickle in Round, Crawford & Mann 1990
Aneumastus laetus (Ant. Mayer) Lange-Bertalot in Lange-Bertalot & Metzeltin 1996
Aneumastus tuscula (Ehrenberg) D.G. Mann & Stickle in Round, Crawford & Mann 1990
Anomoeoneis Pfitzer 1871
Anomoeoneis exilis* var. *azorica Manguin 1942
Anomoeoneis exilis* var. *lanceolata Mayer 1919
Anomoeoneis sculpta (Ehrenberg) Cleve 1895
Anomoeoneis sphaerophora Pfitzer 1871
Asterionella Hassall 1850
Asterionella formosa Hassall 1850
Asterionella gracillima (Hantzsch in Rabenhorst) Heiberg 1863
Aulacoseira Thwaites 1848
Aulacoseira alpigena (Grunow) Krammer 1991
Aulacoseira ambigua (Grunow) Simonsen 1979
Aulacoseira crenulata (Ehrenberg) Thwaites 1848
Aulacoseira distans (Ehrenberg) Simonsen 1979
Aulacoseira distans* var. *africana (O. Müller) Simonsen 1979
Aulacoseira distans* var. *nivalis (W. Smith) E.Y. Haworth 1990
Aulacoseira granulata (Ehrenberg) Simonsen 1979
Aulacoseira granulata* f. *curvata (Hustedt) Simonsen 1979
Aulacoseira granulata* var. *angustissima (O. Müller) Simonsen 1979
Aulacoseira islandica (O. Müller) Simonsen 1979
Aulacoseira islandica* subsp. *helvetica (O. Müller) Simonsen 1979
Aulacoseira italica (Ehrenberg) Simonsen 1979
Aulacoseira italica* var. *tenuissima (Grunow) Simonsen 1979
Aulacoseira lacustris* f. *tenuior (Grunow) Houk, Klee & Passauer 2007
Aulacoseira lirata (Ehrenberg) R. Ross in Hartley 1986
Aulacoseira muzzanensis (F. Meister) Krammer 1991
Aulacoseira perglabra (Østrup) E.Y. Haworth 1990
Aulacoseira subarctica (O. Müller) E.Y. Haworth 1990
Aulacoseira subarctica* f. *recta (O. Müller) Krammer in Krammer & Lange-Bertalot 1991a
Aulacoseira tethera E.Y. Haworth 1990
Auliscus Ehrenberg 1843
Auliscus cylindricus Ehrenberg 1844
Bacillaria J.F. Gmelin 1788
Bacillaria paradoxa J.F. Gmelin in Linneaeus 1788
Bacillaria paxillifera (O.F. Müller) Hendey 1951
Belonastrum (Lemmermann) Round & N.I. Maidana 2001
Belonastrum berolinensis (Lemmermann) Round & N.I. Maidana 2001
Biddulphia Gray 1821
Biddulphia amphicephala (Ehrenberg) Ralfs in A. Pritchard 1861
Biddulphia brevis Ehrenberg 1845
Biremis D.G. Mann & E.J. Cox in Round, Crawford & Mann 1990
Biremis zachariasii (Reichelt) Edlund, N.A. Andresen & N. Soninkhisig 2001
Brachysira Kützing 1836
Brachysira brebissonii R. Ross in B. Hartley 1986
Brachysira brebissonii* f. *thermalis (Grunow in Van Heurck) R. Ross in B. Hartley 1986
Brachysira exilis (Kützing) Round & D.G. Mann 1981
Brachysira microcephala (Kützing) Compère 1986
Brachysira neoexilis Lange-Bertalot in Lange-Bertalot & Moser 1994
Brachysira procera Lange-Bertalot & Gerd Moser 1994
Brachysira serians (Brébisson) Round & D.G. Mann 1981
Brachysira spectabilis (Manguin) Lange-Bertalot & Gerd Moser 1994
Brachysira styriaca (Grunow in Van Heurck) R. Ross in B. Hartley 1986
Brachysira vitrea (Grunow) R. Ross in B. Hartley 1986
Brachysira zellensis (Grunow) Round & D.G. Mann 1981
Caloneis Cleve 1894
Caloneis alpestris (Grunow) Cleve 1894
Caloneis amphisbaena (Bory) Cleve 1894
Caloneis bacillum (Grunow) Cleve 1894

Caloneis bacillum* var. *fontinalis (Grunow in Van Heurck) Cleve 1894
Caloneis branderii (Hustedt) Krammer in Krammer & Lange-Bertalot 1985
Caloneis clevei* f. *inaequalis Manguin 1942
Caloneis fontinalis (Grunow) Lange-Bertalot & E. Reichardt 1996
Caloneis hyalina Hustedt 1937
Caloneis lagerstedtii (Lagerstedt) Cholnoky 1957
Caloneis lepidula (Grunow in Van Heurck) Cleve 1894
Caloneis leptosoma (Grunow) Krammer in Krammer & Lange-Bertalot 1985
Caloneis molaris (Grunow) Krammer in Krammer & Lange-Bertalot 1985
Caloneis permagna (J.W. Bailey) Cleve 1894
Caloneis pulchra Messikommer 1927
Caloneis schumanniana (Grunow in Van Heurck) Cleve 1894
Caloneis silicula (Ehrenberg) Cleve 1894
Caloneis silicula* f. *alpina (Cleve) Krammer in Krammer & Lange-Bertalot 1985
Caloneis silicula* var. *genuina (Cleve) Ant. Mayer 1941
Caloneis silicula* var. *gibberula (Kützing) Cleve-Euler 1932
Caloneis silicula* var. *limosa (Kützing) VanLandingham 1968
Caloneis sublinearis (Grunow) Krammer in Krammer & Lange-Bertalot 1985
Caloneis thermalis (Grunow) Krammer in Krammer & Lange-Bertalot 1985
Caloneis undosa Krammer in Lange-Bertalot & Krammer 1987
Caloneis ventricosa (Ehrenberg) F. Meister 1912
Campylodiscus Ehrenberg ex Kützing 1844
Campylodiscus costatus W. Smith 1851
Campylodiscus hibernicus Ehrenberg 1845
Campylodiscus noricus Ehrenberg ex Kützing 1844
Campylosira Grunow ex Van Heurck 1881
Campylosira cymbelliformis (A.W.F. Schmidt) Grunow in Van Heurck 1881
Capartogramma H. Kufferath 1956
Capartogramma crucicula (Grunow ex Cleve) Ross 1963
Cavinula D.G. Mann & Stickle in Round, Crawford & Mann 1990
Cavinula cocconeiformis (W. Gregory ex Greville) D.G. Mann & Stickle 1990
Cavinula lacustris (W. Gregory) D.G. Mann & Stickle in Round, Crawford & Mann 1990
Cavinula lapidosa (Krasske) Lange-Bertalot in Lange-Bertalot & Metzeltin 1996
Cavinula scutiformis (Grunow ex A.W.F. Schmidt) D.G. Mann & Stickle 1990
Cavinula variostriata (Krasske) D.G. Mann in Round, Crawford & Mann 1990
Ceratoneis Ehrenberg 1839
Ceratoneis arcus* var. *amphioxys (Rabenhorst) Brun 1880
Ceratoneis arcus* f. *arcuata C. Zimmermann 1915a
Ceratoneis arcus* var. *linearis Holmboe 1899
Ceratoneis arcus* f. *semirecta C. Zimmermann 1915a
Ceratoneis arcus* f. *trigibba C. Zimmermann 1915a
Chamaepinnularia Lange-Bertalot & Krammer in Lange-Bertalot & Metzeltin 1996
Chamaepinnularia evanida (Hustedt) Lange-Bertalot in Lange-Bertalot & Metzeltin 1996
Chamaepinnularia hassiaca (Krasske) Cantonati & Lange-Bertalot 2009
Chamaepinnularia mediocris (Krasske) Lange-Bertalot in Lange-Bertalot & Metzeltin 1996
Chamaepinnularia soehrensis (Krasske) Lange-Bertalot & Krammer 1996
Chamaepinnularia soehrensis* var. *muscicola (J.B. Petersen) Lange-Bertalot & Krammer in Lange-Bertalot & Metzeltin 1996
Chamaepinnularia submuscicola (Krasske) Lange-Bertalot in Moser, Lange-Bertalot & Metzeltin 1998
Cocconeis Ehrenberg 1837
Cocconeis decussata Ehrenberg 1843
Cocconeis disculus (Schumann) Cleve 1895
Cocconeis euglypta Ehrenberg 1854
Cocconeis lineata Ehrenberg 1854
Cocconeis molesta Kützing 1844
Cocconeis molesta* var. *amygdalina (Brébisson manuscript, Van Heurck) Cleve in Schmidt 1894
Cocconeis neodiminuta Krammer 1990
Cocconeis pediculus Ehrenberg 1838
Cocconeis placentula Ehrenberg 1838
Cocconeis placentula* var. *klinoraphis Geitler 1927
Cocconeis pseudolineata (Geitler) Lange-Bertalot in Werum & Lange-Bertalot 2004
Cocconeis scutellum Ehrenberg 1838
Cocconeis scutellum* var. *genuina Cleve 1895
Cocconeis striata Ehrenberg 1843
Coscinodiscus Ehrenberg 1839
Coscinodiscus africanus C. Janisch in Schmidt 1878
Coscinodiscus curvatulus Grunow in Schmidt 1878
Coscinodiscus decipiens Grunow in Van Heurck 1882
Coscinodiscus excentricus Ehrenberg 1840
Coscinodiscus lineatus Ehrenberg 1839
Coscinodiscus nodulifer A.W.F. Schmidt in Schmidt 1878
Coscinodiscus nodulifer* f. *minor Tempère & Peragallo 1914
Coscinodiscus oculus-iridis Ehrenberg emend Sancetta 1987

COSMIONEIS D.G. Mann & Stickle in Round, Crawford & Mann 1990
Cosmioneis incognita (Krasske) Lange-Bertalot in Werum & Lange-Bertalot 2004
Cosmioneis pusilla (W. Smith) D.G. Mann & Stickle in Round, Crawford & Mann 1990
CRATICULA Grunow 1867
Craticula accomoda (Hustedt) D.G. Mann in Round, Crawford & Mann 1990
Craticula ambigua (Ehrenberg) D.G. Mann in Round, Crawford & Mann 1990
Craticula cuspidata (Kützing) D.G. Mann in Round, Crawford & Mann 1990
Craticula halophila (Grunow ex Van Heurck) D.G. Mann in Round, Crawford & Mann 1990
Craticula halophila* f. *robusta (Hustedt) Czarnecki 1994
Craticula halophilioides (Hustedt) Lange-Bertalot 2001
Craticula minusculoides (Hustedt) Lange-Bertalot 2001
Craticula molesta (Krasske) Lange-Bertalot & Willmann 1996
Craticula molestiformis (Hustedt) Lange-Bertalot 2001
Craticula riparia (Hustedt) Lange-Bertalot 1993
Craticula submolesta (Hustedt) Lange-Bertalot in Lange-Bertalot & Metzeltin 1996
CTENOPHORA (Grunow) D.M. Williams & Round 1986
Ctenophora pulchella (Ralfs ex Kützing) D.M. Williams & Round 1986
Ctenophora pulchella* var. *lanceolata (O'Meara) Bukhtiyarova 1995
CYCLOSTEPHANOS Round ex E.C. Theriot, Håkansson, Kociolek, Round & Stoermer 1987
Cyclostephanos dubius (Fricke) Round validated by E.C. Theriot et al. 1987
Cyclostephanos invisitatus (M.H. Hohn & Hellerman) E.C. Theriot, Stoermer & Håkansson 1987
CYCLOTELLA (Kützing) Brébisson 1838
Cyclotella atomus Hustedt 1937
Cyclotella catenata (Brun) H. Bachmann 1911
Cyclotella chaetoceras Lemmermann 1900
Cyclotella comensis Grunow in Van Heurck 1882
Cyclotella comta (Ehrenberg) Kützing 1849
Cyclotella cryptica Reimann, Lewin & Guillard 1963
Cyclotella distinguenda Hustedt 1927
Cyclotella gordonensis H.J. Kling & Håkansson 1988
Cyclotella iris Brun & Héribaud in Héribaud 1893
Cyclotella iris* var. *ovalis Mohan 1989
Cyclotella kuetzingiana Thwaites 1848
Cyclotella meduanae H. Germain 1981
Cyclotella melosiroides (Kirchner in Schroter & Kirchner) Lemmermann 1900
Cyclotella meneghiniana Kützing 1844
Cyclotella meneghiniana* var. *rectangulata (Brébisson) Grunow in Van Heurck 1882
Cyclotella ocellata Pantocsek 1902
Cyclotella operculata (C. Agardh) Brébisson 1838
Cyclotella planctonica Brunnthaler 1901
Cyclotella striata (Kützing) Grunow in Cleve & Grunow 1880
CYLINDROTHECA Rabenhorst 1859
Cylindrotheca gracilis (Brébisson) Grunow emend Reimann & Lewin 1964
CYMATOPLEURA W. Smith 1851
Cymatopleura elliptica (Brébisson ex Kützing) W. Smith 1851
Cymatopleura solea (Brébisson in Brébisson & Godey) W. Smith 1851
Cymatopleura solea* var. *apiculata (W. Smith) Ralfs in Pritchard 1861
CYMATOSIRA Grunow 1862
Cymatosira belgica Grunow in Van Heurck 1881
CYMBELLA C. Agardh 1830
Cymbella aequalis* var. *subaequalis (Grunow in Van Heurck) Ant. Mayer 1919
Cymbella affinis Kützing 1844
Cymbella amphicephala Nägeli in Kützing 1849
Cymbella amphioxys (Kützing) Cleve 1894
Cymbella aspera (Ehrenberg) Cleve 1894
Cymbella cesatii* f. *minor Manguin 1942
Cymbella cistula (Hemprich in Hemprich & Ehrenberg) Kirchner 1878
Cymbella cistula* var. *maculata (Kützing) Van Heurck 1885
Cymbella crassa (Grunow) Krammer 2002
Cymbella cuspidata Kützing 1844
Cymbella cuspidata* var. *naviculiformis (Auerswald in Rabenhorst) Rabenhorst 1864
Cymbella cymbiformis C. Agardh 1830
Cymbella cymbiformis* var. *jimboi (Pantocsek) Cleve-Euler 1955
Cymbella cymbiformis* var. *parva (W. Smith) Van Heurck 1885
Cymbella dicephala (Ehrenberg) Holmboe 1901
Cymbella ehrenbergii Kützing 1844
Cymbella excisa Kützing 1844
Cymbella gastroides (Kützing) Kützing 1844
Cymbella gracilis (Ehrenberg) Kützing 1844
Cymbella gracilis* var. *capitata Willi Krieger 1930
Cymbella gracilis* var. *laevis (Naegeli in Kützing) Rabenhorst 1864
Cymbella gracilis* var. *rotundata Willi Krieger 1930
Cymbella helvetica Kützing 1844
Cymbella heteropleura (Ehrenberg) Kützing 1844
Cymbella hungarica (Grunow in Schmidt 1875) Pantocsek 1902

Cymbella hustedtii Krasske 1923a
Cymbella laevis Nägeli in Rabenhorst 1863
Cymbella lanceolata (C. Agardh) C. Agardh 1830
Cymbella lanceolata* var. *boeckii (Ehrenberg) P.G. Richter 1914
Cymbella lancettula (Krammer) Krammer 2002
Cymbella leptoceras (Ehrenberg) Kützing 1844
Cymbella maculata Kützing 1844
Cymbella obtusa W. Gregory 1856
Cymbella obtusiuscula Kützing 1844
Cymbella parva (W. Smith) Wolle 1890
Cymbella perpusilla* var. *azorica Manguin 1942
Cymbella reinhardtii Grunow in Schmidt 1875
Cymbella simonsenii Krammer in Krammer & Lange-Bertalot 1985
Cymbella tumida (Brébisson in Kützing) Van Heurck 1882-1885
Cymbella tumidula Grunow in Schmidt 1875
Cymbella turgida W. Gregory 1856
Cymbella turgidula Grunow in Schmidt 1875
Cymbopleura (Krammer) Krammer 1999
Cymbopleura amphicephala (Nägeli) Krammer 2003
Cymbopleura anglica (Lagerstedt) Krammer 2003
Cymbopleura hauckii (Van Heurck) Krammer 2003
Cymbopleura incerta (Grunow) Krammer 2003
Cymbopleura lata (Grunow) Krammer 2003
Cymbopleura naviculiformis (Auerswald ex Heiberg) Krammer 2003
Delicata Krammer 2003
Delicata delicatula (Kützing) Krammer 2003
Denticella Ehrenberg 1838
Denticella gracilis Ehrenberg 1840
Denticula Kützing 1844
Denticula crassula Nägeli in Kützing 1849
Denticula elegans Kützing 1844
Denticula frigida Kützing 1844
Denticula kuetzingii Grunow 1862
Denticula subtilis Grunow 1862
Denticula tenuis Kützing 1844
Denticula tenuis* var. *inflata (W. Smith) Grunow in Van Heurck 1882-1885
Denticula vanheurcki Brun 1891
Diadesmis Kützing 1844
Diadesmis biceps Arnott
Diadesmis confervacea Kützing 1844
Diadesmis contenta (Grunow ex Van Heurck) D.G. Mann in Round, Crawford & Mann 1990
Diadesmis contenta* var. *biceps (Grunow in Van Heurck) Hamilton 1992
Diadesmis contenta* var. *parallela (J.B. Petersen) Aboal 2003
Diadesmis gallica W. Smith 1857
Diadesmis perpusilla (Grunow) D.G. Mann in Round, Crawford & Mann 1990
Diatoma De Candolle in Lamarck & De Candolle 1805
Diatoma anceps (Ehrenberg) Kirchner 1878
Diatoma elongatum (Lyngbye) C. Agardh 1824
Diatoma hyemale (Lyngbye) Heiberg 1863
Diatoma mesodon Kützing 1844
Diatoma mesoleptum Kützing 1844
Diatoma obtusum (Kützing) Kirchner 1878
Diatoma pectinale (Nitzsch) Kützing 1844
Diatoma tenuis C. Agardh 1824
Diatoma vulgare* var. *productum (***producta***) Grunow 1862
Diatoma vulgaris Bory 1831
Diatomella Greville 1855
Diatomella balfouriana Greville 1855
Didymosphenia M. Schmidt in Schmidt 1899
Didymosphenia geminata (Lyngbye) M. Schmidt in Schmidt 1899
Diploneis (Ehrenberg) Cleve 1894
Diploneis apis (Ehrenberg) Ehrenberg 1845
Diploneis didyma (A.W.F. Schmidt in Schmidt 1881) Mills 1934
Diploneis elliptica (Kützing) Cleve 1894
Diploneis entomon (Ehrenberg) Ehrenberg 1845
Diploneis faba Ehrenberg 1845
Diploneis finnica (Ehrenberg) Cleve 1891
Diploneis interrupta (Kützing) Cleve 1894
Diploneis marginestriata Hustedt 1922
Diploneis minuta J.B. Petersen 1928
Diploneis nitescens (W. Gregory) Cleve 1894
Diploneis oblongella (Nägeli in Kützing) Ross 1947
Diploneis oculata (Brébisson in Desmazières) Cleve 1894
Diploneis ovalis (Hilse in Rabenhorst) Cleve 1891
Diploneis pseudovalis Hustedt 1930

Diploneis puella (Schumann) Cleve 1894
DISCOSTELLA Houk & Klee 2004
Discostella glomerata (Bachmann) Houk & Klee 2004
Discostella pseudostelligera (Hustedt) Houk & Klee 2004
Discostella stelligera (Cleve & Grunow) Houk & Klee 2004
ELLERBECKIA R.M. Crawford 1988
Ellerbeckia arenaria (M.S. Moore ex Ralfs) R.M. Crawford 1988
Ellerbeckia sol (Ehrenberg) R.M. Crawford & Sims 2006
ENCYONEMA Kützing 1833
Encyonema alpinum (Grunow) Mann in Round, Crawford & Mann 1990
Encyonema brehmii (Hustedt) D.G. Mann in Round, Crawford & Mann 1990
Encyonema caespitosum Kützing 1849
Encyonema elginense (Krammer) D.G. Mann in Round, Crawford & Mann 1990
Encyonema gaeumannii (F. Meister) Krammer 1997
Encyonema gracile Rabenhorst 1853
Encyonema hebridicum (W. Gregory) Grunow in Cleve & Möller 1877
Encyonema mesianum (Cholnoky) D.G. Mann in Round, Crawford & Mann 1990
Encyonema minutum (Hilse in Rabenhorst) D.G. Mann in Round, Crawford & Mann 1990
Encyonema muelleri (Hustedt) D.G. Mann in Round, Crawford & Mann 1990
Encyonema neogracile Krammer 1997
Encyonema paucistriatum (Cleve-Euler) Mann in Round, Crawford & Mann 1990
Encyonema perpusillum (A. Cleve) D.G. Mann in Round, Crawford & Mann 1990
Encyonema prostratum (Berkeley) Ralfs 1845
Encyonema rostratum Krammer 1997
Encyonema silesiacum (Bleisch in Rabenhorst) D.G. Mann in Round, Crawford & Mann 1990
Encyonema ventricosum (Kützing) Grunow in Schmidt 1875
Encyonema vulgare Krammer 1997
Encyonema vulgare* var. *intermedia (Manguin) Krammer 1997
ENCYONOPSIS Krammer 1997
Encyonopsis aequalis (W. Smith) Krammer 1997
Encyonopsis cesatii (Rabenhorst) Krammer 1997
Encyonopsis falaisensis (Grunow) Krammer 1997
Encyonopsis microcephala (Grunow) Krammer 1997
Encyonopsis tavirana Krammer 1997
ENTOMONEIS (Ehrenberg) Ehrenberg 1845
Entomoneis alata (Ehrenberg) Reimer in Patrick & Reimer 1975
Entomoneis paludosa (W. Smith) Reimer in Patrick & Reimer 1975
EOLIMNA Lange-Bertalot & W. Schiller in Schiller & Lange-Bertalot 1997
Eolimna minima (Grunow in Van Heurck) Lange-Bertalot 1998
Eolimna subminuscula (Manguin) Gerd Moser, Lange-Bertalot & Metzeltin 1998
Eolimna submuralis (Hustedt) Lange-Bertalot & Kulikovskiy in Kulikovskiy et al. 2010
EPITHEMIA Kützing 1844
Epithemia adnata (Kützing) Brébisson 1838
Epithemia adnata* var. *porcellus (Kützing) R.M. Patrick in Patrick & Reimer 1975
Epithemia adnata* var. *saxonica (Kützing) R.M. Patrick in Patrick & Reimer 1975
Epithemia argus (Ehrenberg) Kützing 1844
Epithemia argus* var. *alpestris (W. Smith) Grunow 1862
Epithemia argus* var. *capitata Fricke in Schmidt 1904
Epithemia faba (Ehrenberg) Kützing 1844
Epithemia ocellata (Ehrenberg) Kützing 1844
Epithemia reichelti Fricke in Schmidt 1904
Epithemia smithii Carruthers 1864
Epithemia sorex Kützing 1844
Epithemia sorex* var. *gracilis Hustedt 1922
Epithemia turgida (Ehrenberg) Kützing 1844
Epithemia turgida* var. *granulata (Ehrenberg) Brun 1880
Epithemia zebra (Ehrenberg) Kützing 1844
EUCOCCONEIS Cleve ex F. Meister 1912
Eucocconeis austriaca (Hustedt) Lange-Bertalot apud Lange-Bertalot & Genkal 1999
Eucocconeis flexella (Kützing) F. Meister 1912
EUNOTIA Ehrenberg 1837
Eunotia alpina (Nägeli in Kützing) Hustedt in Schmidt 1913
Eunotia arculus Lange-Bertalot & Nörpel in Krammer & Lange-Bertalot 1991a
Eunotia arcus Ehrenberg 1838
Eunotia arcus* var. *bidens Grunow in Van Heurck 1882-1885
Eunotia arcus* var. *curtum Grunow 1862
Eunotia arcus* var. *fallax Hustedt 1930
Eunotia arcus* var. *minor Grunow in Van Heurck 1882-1885
Eunotia bicapitata Grunow in Van Heurck 1882-1885
Eunotia bidens Ehrenberg 1843
Eunotia bidentula W. Smith 1856
Eunotia bilunaris (Ehrenberg) Schaarschmidt 1880
Eunotia bilunaris* var. *linearis (Okuno) Lange-Bertalot & Nörpel 1991a
Eunotia circumborealis Lange-Bertalot & Nörpel in Lange-Bertalot 1993
Eunotia diodon Ehrenberg 1837

Eunotia exgracilis Åke Berg in man. Cleve-Euler 1953
Eunotia exigua (Brébisson in Kützing) Rabenhorst 1864
Eunotia exigua* var. *tenella (Grunow) Nörpel & Alles in Alles, Nörpel & Lange-Bertalot 1991
Eunotia faba (Ehrenberg) Grunow in Van Heurck 1882-1885
Eunotia fallax A. Cleve 1895
Eunotia fidelensis C. Zimmermann 1915b
Eunotia flexuosa (Brébisson in Kützing) Kützing 1849
Eunotia flexuosa* var. *vasconiensis Manguin in Allorge & Manguin 1941
Eunotia formica Ehrenberg 1843
Eunotia formica* var. *intermedia Grunow 1865
Eunotia glacialis F. Meister 1912
Eunotia gracilis W. Smith 1853
Eunotia gracilis* var. *ventralis Ehrenberg
Eunotia groenlandica (Grunow) Nörpel-Schempp & Lange-Bertalot 1996
Eunotia implicata Nörpel, Alles & Lange-Bertalot in Alles, Nörpel & Lange-Bertalot 1991
Eunotia impressa* var. *angusta Van Heurck 1881
Eunotia incisa W. Gregory 1854
Eunotia inflata (Grunow) Nörpel-Schempp & Lange-Bertalot 1996
Eunotia intermedia (Krasske ex Hustedt) Nörpel & Lange-Bertalot in Lange-Bertalot 1993
Eunotia lapponica Grunow in Cleve-Euler 1895
Eunotia lunaris (Ehrenberg) Grunow 1877
Eunotia lunaris* var. *bilunaris (Ehrenberg) Grunow in Van Heurck 1882-1885
Eunotia lunaris* var. *excisa Grunow in Van Heurck 1881
Eunotia lunaris* var. *subarcuata (Naegeli in Kützing) Grunow in Van Heurck 1881
Eunotia microcephala Krasske 1932
Eunotia microcephala* var. *tridentata (Ant. Mayer) Hustedt 1932
Eunotia minor (Kützing) Grunow in Van Heurck 1881
Eunotia minutula Grunow 1862
Eunotia monodon Ehrenberg 1843
Eunotia monodon* f. *curta Grunow in Van Heurck 1882-1885
Eunotia monodon* var. *major (W. Smith) Hustedt 1930
Eunotia mucophila (Lange-Bertalot & Nörpel-Schempp) Lange-Bertalot 2007
Eunotia naegelii Migula 1907
Eunotia neocompacta A. Mayama in Mayama & Kawashima 1998
Eunotia paludosa Grunow 1862
Eunotia paludosa* var. *trinacria (Krasske) Nörpel & Alles 1991
Eunotia parallela Ehrenberg 1843
Eunotia pectinalis (Kützing) Rabenhorst 1864
Eunotia pectinalis* f. *affines Manguin 1942
Eunotia pectinalis* f. *curta Van Heurck 1881
Eunotia pectinalis* f. *elongata Van Heurck 1882-1885
Eunotia pectinalis* f. *impressa (Ehrenberg) Hustedt 1930
Eunotia pectinalis* var. *rostrata H. Germain 1981
Eunotia pectinalis* var. *undulata (Ralfs) Rabenhorst 1864
Eunotia pectinalis* var. *ventralis (Ehrenberg; Ehrenberg) Hustedt 1911
Eunotia pectinalis* var. *ventricosa (Ehrenberg) Grunow in Van Heurck 1882-1885
Eunotia pectinoides C. Zimmermann 1915b
Eunotia praerupta Ehrenberg 1843
Eunotia praerupta* var. *muscicola J.B. Petersen 1928
Eunotia rhomboidea Hustedt 1950
Eunotia robusta Ralfs in Pritchard 1861
Eunotia septentrionalis Østrup 1897
Eunotia serpentina Ehrenberg 1854
Eunotia serra Ehrenberg 1837
Eunotia serra* var. *diadema (Ehrenberg) R.M. Patrick 1958
Eunotia siolii Hustedt 1952
Eunotia soleirolii (Kützing) Rabenhorst 1864
Eunotia subarcuatoides Alles, Nörpel & Lange-Bertalot 1991
Eunotia submonodon Hustedt emend Gil 1989
Eunotia sudetica O. Müller 1898
Eunotia sudetica* var. *bidens Hustedt in Schmidt 1913
Eunotia tetraodon Ehrenberg 1838
Eunotia torula M.H. Hohn 1961
Eunotia trinacria* var. *undulata Hustedt 1930
Eunotia triodon Ehrenberg 1837
Eunotia valida Hustedt 1930
Eunotia veneris (Kützing) De Toni 1892
Eunotia ventricosa (Ehrenberg)
Fallacia Stickle & D.G. Mann in Round, Crawford & Mann 1990
Fallacia enigmatica (H. Germain) Lange-Bertalot & Werum in Werum & Lange-Bertalot 2004
Fallacia helensis (Schulz) D.G. Mann in Round, Crawford & Mann 1990
Fallacia insociabilis (Krasske) D.G. Mann in Round, Crawford & Mann 1990
Fallacia monoculata (Hustedt) D.G. Mann in Round, Crawford & Mann 1990
Fallacia pygmaea (Kützing) Stickle & D.G. Mann in Round, Crawford & Mann 1990
Fallacia subhamulata (Grunow in Van Heurck) Bukhtiyarova 1995

Fallacia vitrea (Østrup) D.G. Mann in Round, Crawford & Mann 1990
FISTULIFERA Lange-Bertalot 1997
Fistulifera pelliculosa (Brébisson) Lange-Bertalot 1997
Fistulifera saprophila (Lange-Bertalot & Bonik) Lange-Bertalot 1997
FRAGILARIA Lyngbye 1819
Fragilaria arcus (Ehrenberg) Cleve 1898
Fragilaria bidens Heiberg 1863
Fragilaria capucina Desmazières 1825
Fragilaria capucina* var. *acuta (Ehrenberg) Rabenhorst 1864
Fragilaria capucina* subsp. *amphicephala (Kützing) Lange-Bertalot 1993
Fragilaria capucina* var. *austriaca (Grunow) Lange-Bertalot 1980
Fragilaria capucina* var. *capitellata (Grunow) Lange-Bertalot 1991
Fragilaria capucina* var. *distans (Grunow) Lange-Bertalot 1991
Fragilaria capucina* var. *fragilarioides (Grunow) Ludwig & Flores 1997
Fragilaria capucina* var. *lanceolata Grunow in Van Heurck 1881
Fragilaria capucina* var. *mesolepta (Rabenhorst) Rabenhorst 1864
Fragilaria capucina* f. *minuscula No authors mentioned
Fragilaria crotonensis Kitton 1869
Fragilaria danica (Kützing) Lange-Bertalot in Lange-Bertalot & Metzeltin 1996
Fragilaria delicatissima (W. Smith) Lange-Bertalot 1980
Fragilaria dilatata (Brébisson) Lange-Bertalot 1993
Fragilaria exigua Grunow in Cleve & Möller 1878
Fragilaria famelica (Kützing) Lange-Bertalot 1980
Fragilaria gracilis Østrup 1910
Fragilaria henryi Lange-Bertalot apud Lange-Bertalot & Genkal 1999
Fragilaria incisa (C.S. Boyer) Lange-Bertalot 1980
Fragilaria inflata (Heiden) Hustedt 1931
Fragilaria intermedia (Grunow) Grunow in Van Heurck 1881
Fragilaria islandica Grunow in Van Heurck 1881
Fragilaria lapponica Grunow in Van Heurck 1881
Fragilaria miniscula (Grunow in Van Heurck) D.M. Williams & Round 1987
Fragilaria montana (Krasske) Lange-Bertalot 1980
Fragilaria mutabilis (W. Smith) Grunow 1862
Fragilaria nana (F. Meister) Lange-Bertalot 1980
Fragilaria nanana Lange-Bertalot in Krammer & Lange-Bertalot 1991a
Fragilaria neoproducta Lange-Bertalot in Krammer & Lange-Bertalot 1991
Fragilaria pinnata* var. *robusta Manguin 1964
Fragilaria punctatostriata Manguin 1942
Fragilaria radians (Kützing) D.M. Williams & Round 1987
Fragilaria rhabdosoma Ehrenberg 1832
Fragilaria rumpens (Kützing) Carlson 1913
Fragilaria socia (J.H. Wallace) Lange-Bertalot 1980
Fragilaria tenera (W. Smith) Lange-Bertalot 1980
Fragilaria tenuicollis Heiberg 1863
Fragilaria ulna* Sippen *angustissima (Grunow) Lange-Bertalot 1991
Fragilaria utermoehlii (Hustedt) Lange-Bertalot 1993
Fragilaria vaucheriae (Kützing) J.B. Petersen 1938
FRAGILARIFORMA D.M. Williams & Round 1988
Fragilariforma constricta (Ehrenberg) D.M. Williams & Round 1988
Fragilariforma virescens (Ralfs) D.M. Williams & Round 1988
Fragilariforma virescens* var. *elliptica (Hustedt) Aboal 2003
FRUSTULIA Rabenhorst 1853
Frustulia crassinervia (Brébisson) Lange-Bertalot & Krammer 1996
Frustulia elongata (Willi Krieger) Lange-Bertalot in Lange-Bertalot & Jahn 2000
Frustulia erifuga Lange-Bertalot & Krammer in Lange-Bertalot & Metzeltin 1996
Frustulia rhomboides (Ehrenberg) De Toni 1891
Frustulia rhomboides* var. *amphipleuroides (Grunow in Cleve & Grunow) De Toni 1891
Frustulia rhomboides* f. *capitata (Ant. Mayer) Hustedt 1930
Frustulia rhomboides* f. *undulata Hustedt 1930
Frustulia rhomboides* var. *viridula (Brébisson ex Kützing) Cleve 1894
Frustulia rostratiformis Lange-Bertalot in Lange-Bertalot & Jahn 2000
Frustulia saxonica Rabenhorst 1848-1860
Frustulia vulgaris (Thwaites) De Toni 1891
Frustulia vulgaris* var. *capitata Krasske 1923
Frustulia vulgaris* f. *parva Cleve-Euler 1952
GEISSLERIA Lange-Bertalot & Metzeltin 1996
Geissleria acceptata (Hustedt) Lange-Bertalot & Metzeltin 1996
Geissleria declivis (Hustedt) Lange-Bertalot in Lange-Bertalot & Metzeltin 1996
Geissleria decussis (Østrup) Lange-Bertalot & Metzeltin 1996
Geissleria ignota (Krasske) Lange-Bertalot & Metzeltin 1996
Geissleria schoenfeldii (Hustedt) Lange-Bertalot & Metzeltin 1996
GLYPHODESMIS Greville 1862
Glyphodesmis varians C. Zimmermann 1915b
Glyphodesmis varians* var. *elegantula C. Zimmermann 1915a
Glyphodesmis varians* var. *elongata C. Zimmermann 1915a

Glyphodesmis varians* var. *genuina C. Zimmermann 1915a
Glyphodesmis varians* var. *tumida C. Zimmermann 1915a
Gomphoneis Cleve 1894
Gomphoneis herculeana (Ehrenberg) Cleve 1894
Gomphonema Ehrenberg 1832
Gomphonema acuminatum Ehrenberg 1832
Gomphonema acuminatum* var. *coronatum (Ehrenberg) Rabenhorst 1864
Gomphonema acuminatum* var. *elongatum (W. Smith) Carruthers 1864
Gomphonema acutiusculum (O. Müller) Cleve-Euler 1955
Gomphonema affine Kützing 1844
Gomphonema angustatum (Kützing) Rabenhorst 1864
Gomphonema angustatum* var. *intermedia Grunow in Van Heurck 1880
Gomphonema angustatum* f. *producta Grunow in Van Heurck 1880
Gomphonema angustum C. Agardh 1831
Gomphonema angustum* var. *lunatum (H. Germain) Aboal 2003
Gomphonema anjae Lange-Bertalot & E. Reichardt 1991
Gomphonema augur Ehrenberg 1840
Gomphonema augur* var. *gautieri Van Heurck 1885
Gomphonema augur* var. *turris (Ehrenberg) Lange-Bertalot 1985
Gomphonema bipunctatum C. Zimmermann 1915b
Gomphonema brebissonii Kützing 1849
Gomphonema capitatum Ehrenberg 1838
Gomphonema clavatum Ehrenberg 1838
Gomphonema clevei Fricke in Schmidt 1902
Gomphonema constrictum Ehrenberg 1832
Gomphonema constrictum* var. *capitatum (Ehrenberg) Grunow 1880
Gomphonema constrictum* var. *curta (Grunow in Van Heurck) Van Heurck 1896
Gomphonema constrictum* var. *subcapitatum Grunow in Van Heurck 1880
Gomphonema dichotomum Kützing 1833
Gomphonema exiguum Kützing 1844
Gomphonema exilissimum (Grunow) Lange-Bertalot & E. Reichardt 1996
Gomphonema gracile Ehrenberg 1838
Gomphonema gracile* var. *auritum (A. Braun) Van Heurck 1885
Gomphonema hebridense W. Gregory 1854
Gomphonema ibericum E. Reichardt 2007
Gomphonema insigne W. Gregory 1856
Gomphonema intricatum Kützing 1844
Gomphonema intricatum var. angustata Brun 1880
Gomphonema lagenula Kützing 1844
Gomphonema lanceolatum Kützing 1844
Gomphonema lapponicum (A. Cleve) Cleve-Euler 1934
Gomphonema laticollum E. Reichardt 2001
Gomphonema longiceps Ehrenberg 1854
Gomphonema longiceps* f. *gracilis Hustedt 1930
Gomphonema longiceps* var. *subclavata (Grunow) Hustedt 1930
Gomphonema micropus Kützing 1844
Gomphonema minutum C. Agardh 1831
Gomphonema minutum* f. *curtum (Hustedt) Lange-Bertalot & E. Reichardt 1993
Gomphonema montanum (Schumann) Grunow in Schneider 1878
Gomphonema montanum* var. *acuminata (Peragallo & Héribaud) Ant. Mayer 1928
Gomphonema mustela Ehrenberg 1854
Gomphonema olivaceum (Hornemann) Kützing 1844
Gomphonema olivaceum* var. *calcarea (Cleve) Van Heurck 1880
Gomphonema olivaceum* var. *minutissima Hustedt 1930
Gomphonema olivaceum* var. *olivaceoides (Hustedt) Lange-Bertalot 1989
Gomphonema parvulius (Lange-Bertalot & E. Reichardt) Lange-Bertalot & E. Reichardt 1996
Gomphonema parvulum (Kützing) Kützing 1849
Gomphonema parvulum* f. *affine Manguin 1942
Gomphonema parvulum f. saprophilum Lange-Bertalot & E. Reichardt in Lange-Bertalot 1993
Gomphonema parvulum var. lanceolata Grunow in Van Heurck 1880
Gomphonema parvulum var. subcapitata Grunow in Van Heurck 1880
Gomphonema parvulum var. subelliptica Cleve 1894
Gomphonema productum (Grunow) Lange-Bertalot & E. Reichardt in Lange-Bertalot 1993
Gomphonema pseudoaugur Lange-Bertalot 1979
Gomphonema pumilum (Grunow) E. Reichardt & Lange-Bertalot 1991
Gomphonema rhombicum Fricke in Schmidt 1904
Gomphonema rosenstockianum Lange-Bertalot & E. Reichardt 1993
Gomphonema sagitta Schumann 1862
Gomphonema sarcophagus W. Gregory 1856
Gomphonema sphaerophorum Ehrenberg 1845d
Gomphonema subclavatum (Grunow in Van Heurck) Grunow 1884
Gomphonema subclavatum* var. *commutatum (Grunow in Van Heurck) Ant. Mayer 1919
Gomphonema subtile Ehrenberg 1843
Gomphonema tenellum Kützing 1844
Gomphonema tergestinum (Grunow in Van Heurck) Fricke in Schmidt 1902

Gomphonema truncatum Ehrenberg 1832
Gomphonema truncatum* var. *capitatum (Ehrenberg) R.M. Patrick in Patrick & Reimer 1975
Gomphonema uniserhombicum E. Reichardt 2005
Gomphonema utae Lange-Bertalot & E. Reichardt apud E. Reichardt 1999
Gomphonema ventricosum W. Gregory 1856
Gomphonema vibrio Ehrenberg 1843
GOMPHOSPHENIA Lange-Bertalot 1995
Gomphosphenia lingulatiformis (Lange-Bertalot & E. Reichardt) Lange-Bertalot 1995
GRAMMATOPHORA Ehrenberg 1840
Grammatophora macilenta W. Smith 1856
Grammatophora oceanica Ehrenberg 1840
Grammatophora serpentina (Ralfs) Ehrenberg 1844
GRAMMONEMA C. Agardh 1832
Grammonema striatula (Lyngbye) C. Agardh 1832
GYROSIGMA Hassall 1845
Gyrosigma acuminatum (Kützing) Rabenhorst 1853
Gyrosigma acuminatum* var. *brebissonii (Grunow in Cleve & Grunow) Cleve 1894
Gyrosigma attenuatum (Kützing) Cleve 1894
Gyrosigma distortum (W. Smith) Cleve 1894
Gyrosigma kuetzingii (Grunow) Cleve 1894
Gyrosigma macrum (W. Smith) Cleve 1894
Gyrosigma nodiferum (Grunow) Reimer in Patrick & Reimer 1966
Gyrosigma obscurum (W. Smith) J.W. Griffith & Henfrey 1856
Gyrosigma scalproides (Rabenhorst) Cleve 1894
Gyrosigma spenceri (W. Smith) J.W. Griffith & Henfrey 1856
Gyrosigma tenuissimum (W. Smith) Cleve 1894
HALAMPHORA (Cleve) Levkov 2009
Halamphora montana (Krasske) Levkov 2009
Halamphora normanii (Rabenhorst) Levkov 2009
Halamphora oligotraphenta (Lange-Bertalot) Levkov 2009
Halamphora turgida (Gregory) Levkov 2009
Halamphora veneta (Kützing) Levkov 2009
HANTZSCHIA Grunow 1877
Hantzschia abundans Lange-Bertalot 1993
Hantzschia amphioxys (Ehrenberg) Grunow in Cleve & Grunow 1880
Hantzschia amphioxys* f. *capitata O. Müller 1909
Hantzschia amphioxys* var. *intermedia Grunow in Van Heurck 1881
Hantzschia amphioxys* var. *longa C. Zimmermann 1914
Hantzschia amphioxys* var. *major Grunow in Van Heurck 1881
Hantzschia amphioxys* var. *vivax Grunow in Cleve & Grunow 1880
Hantzschia elongata (Hantzsch) Grunow in Cleve & Grunow 1880
Hantzschia virgata (Roper) Grunow in Cleve & Grunow 1880
HASLEA Simonsen 1974
Haslea ostrearia (Gaillon) Simonsen 1974
Haslea spicula (Hickie) Bukhtiyarova 1995
HIPPODONTA Lange-Bertalot, Witkowski & Metzeltin 1996
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski 1996
Hippodonta hungarica (Grunow) Lange-Bertalot, Metzeltin & Witkowski 1996
HYALODISCUS Ehrenberg 1845
Hyalodiscus stelliger J.W. Bailey 1854
Hyalodiscus subtilis J.W. Bailey 1854
KARAYEVIA Round & Bukhtiyarova ex Round 1998
Karayevia amoena (Hustedt) Bukhtiyarova 2006
Karayevia bottnica (Cleve) Lange-Bertalot in Krammer & Lange-Bertalot 2004
Karayevia clevei (Grunow) Bukhtiyarova 2006
Karayevia kolbei (Hustedt) Bukhtiyarova 2006
Karayevia laterostrata (Hustedt) Bukhtiyarova 2006
Karayevia oblongella (Østrup) Aboal 2003
Karayevia ploenensis (Hustedt) Bukhtiyarova 2006
Karayevia suchlandtii (Hustedt) Bukhtiyarova 2006
KOBAYASIELLA Lange-Bertalot 1999
Kobayasiella subtilissima (Cleve) Lange-Bertalot 1999
KOLBESIA Round & Bukhtiyarova 1998
Kolbesia gessneri (Hustedt) Aboal 2003
LAUDERIA Cleve 1873
Lauderia borealis Gran 1900
LEMNICOLA Round & Basson 1997
Lemnicola hungarica (Grunow) Round & Basson 1997
LEPTOCYLINDRUS Cleve in J.B. Petersen 1889
Leptocylindrus minimus Gran 1915
LUTICOLA D.G. Mann in Round, Crawford & Mann 1990
Luticola cohnii (Hilse) D.G. Mann in Round, Crawford & Mann 1990
Luticola goeppertiana (Bleisch in Rabenhorst) D.G. Mann in Round, Crawford & Mann 1990
Luticola lagerheimii (Cleve) D.G. Mann in Round, Crawford & Mann 1990
Luticola mutica (Kützing) D.G. Mann in Round, Crawford & Mann 1990

Luticola nivalis (Ehrenberg) D.G. Mann in Round, Crawford & Mann 1990
Luticola undulata (Hilse in Rabenhorst) D.G. Mann in Round, Crawford & Mann 1990
Luticola ventricosa (Kützing) Mann in Round, Crawford & Mann 1990
MARTYANA Round in Round, Crawford & Mann 1990
Martyana atomus (Hustedt) Snoeijs in Snoeijs, Hallfors & Leskinen 1991
MASTOGLOIA Thwaites in Smith 1856
Mastogloia baltica Grunow in Van Heurck 1880
Mastogloia elliptica (C. Agardh) Cleve in Schmidt 1893
Mastogloia elliptica* var. *dansei (Thwaites) Cleve 1895
Mastogloia exigua F.W. Lewis 1861
Mastogloia lacustris (Grunow) Van Heurck 1880
Mastogloia smithii Thwaites in lit. ex W. Smith 1856
Mastogloia smithii* var. *amphicephala Grunow in Van Heurck 1880
MAYAMAEA Lange-Bertalot 1997
Mayamaea agrestis (Hustedt) Lange-Bertalot 2001
Mayamaea atomus (Kützing) Lange-Bertalot 1997
Mayamaea excelsa (Krasske) Lange-Bertalot 1997
Mayamaea fossalis (Krasske) Lange-Bertalot 1997
Mayamaea permitis (Hustedt) Bruder & Medlin 2008
MELOSIRA C. Agardh 1824
Melosira cataractarum* f. *laevis Manguin 1942
Melosira concatenata (Kützing) Rabenhorst 1864
Melosira dickiei (Thwaites) Kützing 1849
Melosira italica* var. *perminuta Cleve-Euler 1951
Melosira jurgensii C. Agardh
Melosira lineata (Dillwyn) C. Agardh 1824
Melosira roeseana* var. *spiralis (Ehrenberg) Grunow in Van Heurck 1882
Melosira undulata (Ehrenberg) Kützing 1844
Melosira varians C. Agardh 1827
MERIDION C. Agardh 1824
Meridion circulare (Greville) C. Agardh 1831
Meridion constrictum Ralfs 1843
MICROCOSTATUS J.R. Johansen & J.C. Sray 1998
Microcostatus krasskei (Hustedt) J.R. Johansen & J.C. Sray 1998
MUELLERIA (Frenguelli) Frenguelli 1945
Muelleria gibbula (Cleve) S. Spaulding & Stoermer 1997
NAVICULA Bory 1822
Navicula alpina Ralfs in Pritchard 1861
Navicula ammophila Grunow 1882
Navicula amphiceros (Ehrenberg) De Toni 1891
Navicula amphigomphus* f. *minor No authors mentioned
Navicula anglica v*ar. *subsalina Grunow in Van Heurck 1880
Navicula angusta Grunow 1860
Navicula aquaedurae Lange-Bertalot in Krammer & Lange-Bertalot 1991b
Navicula arvensis Hustedt 1937
Navicula arvensis* var. *major Lange-Bertalot in Krammer & Lange-Bertalot 1985
Navicula associata Lange-Bertalot & G. Hofmann 2001
Navicula bacillaris (Ehrenberg) De Toni 1891
Navicula bacillum* f. *minor Grunow in Van Heurck 1880
Navicula brasiliana (Cleve) Cleve 1894
Navicula brehmii sensu Hustedt in Schmidt 1934
Navicula cancellata Donkin 1872
Navicula capitatoradiata H. Germain 1981
Navicula cari Ehrenberg 1836
Navicula caterva M.H. Hohn & Hellerman 1963
Navicula cincta (Ehrenberg) Ralfs in Pritchard 1861
Navicula cincta* var. *heufleri (Grunow) Grunow in Van Heurck 1880
Navicula compressicauda A.W.F. Schmidt 1874
Navicula cryptocephala Kützing 1844
Navicula cryptocephala* var. *exilis Grunow in Van Heurck 1880
Navicula cryptocephala* var. *intermedia Grunow in Van Heurck 1880
Navicula cryptocephala* var. *lancettula (Schumann) Grunow in Van Heurck 1880
Navicula cryptocephaloides Hustedt 1937
Navicula cryptotenella Lange-Bertalot in Krammer & Lange-Bertalot 1985
Navicula cryptotenelloides Lange-Bertalot 1993
Navicula cymbula Donkin 1869
Navicula difficillima Hustedt 1950
Navicula digitoradiata (W. Gregory) Ralfs in Pritchard 1861
Navicula dispersa Manguin 1942
Navicula dispersa* f. *constricta Manguin 1942
Navicula dispersa* f. *rostrata Manguin 1942
Navicula dissipata Hustedt in Schmidt 1936
Navicula divergens* f. *minor A.W.F. Schmidt in Schmidt 1876
Navicula duerrenbergiana Hustedt in Schmidt 1934
Navicula eidrigiana Carter 1979

Navicula elliptica* var. *minima Van Heurck 1885
Navicula erifuga Lange-Bertalot in Krammer & Lange-Bertalot 1985
Navicula festiva Krasske 1925
Navicula fusca (W. Gregory) Ralfs in Pritchard 1861
Navicula fusiformis Grunow 1877
Navicula germainii J.H. Wallace 1960
Navicula gibba* var. *brevistriata Van Heurck 1885
Navicula gibberula* var. *oblonga Lagerstedt 1873
Navicula globosa F. Meister 1935
Navicula glomus J.R. Carter & Bailey-Watts 1981
Navicula gracilis Ehrenberg 1832
Navicula gracilis* var. *schizonemoides Van Heurck 1885
Navicula gregaria Donkin 1861
Navicula grimmei Krasske in Hustedt 1930
Navicula halophila* f. *subcapitata (Østrup) Hustedt 1961
Navicula harderi Hustedt in Brendemuhl 1949
Navicula hasta Pantocsek 1892
Navicula heimansii van Dam & Kooijman 1982
Navicula heimansioides Lange-Bertalot 1993
Navicula henriquesii C. Zimmermann 1917
Navicula humilis Donkin 1872
Navicula imperfecta Cleve 1883
Navicula impexa Hustedt 1961
Navicula incerta Grunow in Van Heurck 1880
Navicula infirma Manguin 1942
Navicula lanceolata (C. Agardh) Kützing 1844
Navicula lanceolata* f. *minuta Rabenhorst 1864
Navicula laterostrata Hustedt 1925
Navicula lepidissima Cleve-Euler 1953
Navicula leptostriata E.G. Jørgensen 1948
Navicula libonensis Schoeman 1970
Navicula longa (W. Gregory) Ralfs in Pritchard 1861
Navicula longicephala Hustedt 1944
Navicula lucidula Grunow in Van Heurck 1880
Navicula lundii E. Reichardt 1985
Navicula lusitanica C. Zimmermann 1917
Navicula macra Grunow in Schmidt 1876
Navicula madeirensis Lange-Bertalot 1993
Navicula maidanae Metzeltin & Lange-Bertalot 1998
Navicula margalithii Lange-Bertalot in Krammer & Lange-Bertalot 1985
Navicula medioconvexa Hustedt 1961
Navicula menisculus Schumann 1867
Navicula milthersii Foged 1962
Navicula mimicans Hanna 1932
Navicula minima* var. *atomoides (Grunow in Van Heurck) Cleve 1894
Navicula modica Hustedt 1945
Navicula mutica* var. *gomphonemoides Manguin 1942
Navicula neoventricosa Hustedt 1964
Navicula notha J.H. Wallace 1960
Navicula novaesiberica Lange-Bertalot 1993
Navicula oblonga (Kützing) Kützing 1844
Navicula obsoleta Hustedt 1942
Navicula oligotraphenta Lange-Bertalot & G. Hofmann in Lange-Bertalot 1993
Navicula palpebralis Brébisson in litt., W. Smith 1853
Navicula parvula Ralfs in Pritchard 1861
Navicula peregrina (Ehrenberg) Kützing 1844
Navicula peregrina* var. *meniscus (Schumann) Grunow 1880
Navicula persica Rabenhorst 1853
Navicula peterseni Hustedt 1937
Navicula petersii (Ehrenberg) Kützing 1849
Navicula phyllepta Kützing 1844
Navicula placentula* var. *apiculata Hustedt 1911
Navicula pseudoarvensis Hustedt 1942
Navicula pseudobryophila Hustedt 1942
Navicula pseudoventralis Hustedt in Schmidt 1936
Navicula pupula* f. *capitata (Hustedt) Hustedt 1957
Navicula pupula* var. *genuina Cleve & Grunow 1880
Navicula pupula* f. *minuta Grunow in Van Heurck 1880
Navicula radiosa Kützing 1844
Navicula radiosa* var. *acuta (W. Smith) Grunow 1860
Navicula radiosa* f. *intermedia Manguin 1942
Navicula radiosa* var. *tenella (Brébisson ex Kützing) Van Heurck 1885
Navicula radiosafallax Lange-Bertalot 1993
Navicula recens (Lange-Bertalot) Lange-Bertalot in Krammer & Lange-Bertalot 1985
Navicula reichardtiana Lange-Bertalot 1989

Navicula rhynchocephala Kützing 1844
Navicula rhynchocephala var. dubia Grunow 1860
Navicula rhynchocephala var. elongata Grunow 1860
Navicula rostellata Kützing 1844
Navicula rotaeana (Rabenhorst) Grunow in Van Heurck 1880
Navicula rotaeana* f. *minor tenuistriata Grunow in Van Heurck 1880
Navicula rotaeana* var. *oblongella Grunow in Van Heurck 1880
Navicula rotunda Hustedt 1945
Navicula rupestris O'Meara 1875
Navicula salinarum Grunow 1880
Navicula salinarum* var. *rostrata (Hustedt) Lange-Bertalot 2001
Navicula schadei Krasske 1929
Navicula schroeteri F. Meister 1932
Navicula schroeteri* var. *symmetrica (R.M. Patrick) Lange-Bertalot 1991
Navicula serians Brébisson in Kützing 1844
Navicula serians* var. *minima Grunow in Van Heurck 1880
Navicula simplex Krasske 1925
Navicula simulata Manguin 1942
Navicula slesvicensis Grunow in Van Heurck 1880
Navicula smithii Brébisson 1854
Navicula stankovici Hustedt 1945
Navicula stauroptera* var. *parva (Ehrenberg) Van Heurck 1885
Navicula striolata (Grunow) Lange-Bertalot in Reichardt 1984
Navicula subrotundata Hustedt 1945
Navicula tabellaria* var. *stauroneiformis Van Heurck 1880
Navicula tantula Hustedt 1934
Navicula tenelloides Hustedt 1937
Navicula termes (Ehrenberg) O'Meara 1875
Navicula tridentula Krasske 1923a
Navicula tripunctata (O.F. Müller) Bory 1827
Navicula trivialis Lange-Bertalot 1980
Navicula tumida W. Smith 1853
Navicula tuscula sensu Grunow in Van Heurck 1880
Navicula tuscula* f. *minor Simonsen 1962
Navicula twymaniana R.E.M. Archibald 1966
Navicula unica Salah & G. Tamás 1968
Navicula upsaliensis (Grunow in Van Heurck) Peragallo 1903
Navicula veneta Kützing 1844
Navicula ventricosa Ehrenberg 1830
Navicula viridula (Kützing) Kützing 1844
Navicula viridula* f. *minor Grunow in Van Heurck 1880
Navicula vitrea (Østrup) Hustedt 1930
Navicula vulpina Kützing 1844
Naviculadicta Lange-Bertalot in Lange Bertalot & Moser 1994
Naviculadicta vaucheriae (J.B. Petersen) Lange-Bertalot 1994
Naviculadicta vitabunda (Hustedt) Lange-Bertalot in Lange-Bertalot & Moser 1994
Navicymbula Krammer 2003
Navicymbula pusilla (Grunow in A. Schmidt) Krammer 2003
Neidium Pfitzer 1871
Neidium affine (Ehrenberg) Pfitzer 1871
Neidium affine* var. *amphirhynchus (Ehrenberg) Cleve 1894
Neidium alpinum Hustedt 1943
Neidium amphigomphus (Ehrenberg) Pfitzer 1871
Neidium amphirhynchus* var. *majus (Cleve) F. Meister 1912
Neidium amphirhynchus* var. *medium (Cleve-Euler) Cleve-Euler 1955
Neidium amphirhynchus* var. *undulatum (Grunow) F. Meister 1912
Neidium ampliatum (Ehrenberg) Krammer in Krammer & Lange-Bertalot 1985
Neidium apiculatum Reimer 1959
Neidium binodis (Ehrenberg) Hustedt 1945
Neidium bisulcatum (Lagerstedt) Cleve 1894
Neidium densestriatum (Østrup) Krammer in Krammer & Lange-Bertalot 1985
Neidium dilatatum (Ehrenberg) Cleve 1894
Neidium dubium (Ehrenberg) Cleve 1894
Neidium hercynicum Ant. Mayer 1917
Neidium iridis (Ehrenberg) Cleve 1894
Neidium iridis* var. *amphigomphus sensu Mayer 1925
Neidium iridis* var. *firma (Kützing) Ant. Mayer 1913
Neidium longiceps (W. Gregory) Cleve-Euler 1955
Neidium productum (W. Smith) Cleve 1894
Neidium septentrionalis Cleve-Euler 1939
Neidium vernale (Reichelt ex Hustedt) Metzeltin & Lange-Bertalot 2007
Nitzschia Hassall 1845
Nitzschia abbreviata Hustedt in Schmidt 1924
Nitzschia acicularioides Hustedt 1959
Nitzschia acicularis (Kützing) W. Smith 1853

Nitzschia acicularis* var. *reversa No authors mentioned
Nitzschia acidoclinata Lange-Bertalot 1976
Nitzschia actinastroides (Lemmermann) Goor 1925
Nitzschia acula Hantzsch ex Cleve & Grunow 1880
Nitzschia agnita Hustedt 1957
Nitzschia alpina Hustedt 1943
Nitzschia amphibia Grunow 1862
Nitzschia amphibia* f. *abbreviata Manguin 1942
Nitzschia amphibioides Hustedt 1942
Nitzschia archibaldii Lange-Bertalot 1980
Nitzschia aurariae Cholnoky 1965
Nitzschia bacillum Hustedt 1921
Nitzschia bilobata W. Smith 1853
Nitzschia brevissima Grunow in Van Heurck 1881
Nitzschia calida Grunow in Cleve & Grunow 1880
Nitzschia capitata Østrup 1913
Nitzschia capitellata Hustedt in Schmidt 1922
Nitzschia capitellata* var. *tenuirostris (Grunow in Van Heurck) Bukhtiyarova 1995
Nitzschia circumsuta (J.W. Bailey) Grunow 1878
Nitzschia clausii Hantzsch 1860
Nitzschia clausii* f. *curvirostrata Manguin 1942
Nitzschia closterium (Ehrenberg) W. Smith 1853
Nitzschia coarctata Grunow 1880
Nitzschia communis Rabenhorst in Grunow 1862
Nitzschia communis* var. *obtusa Grunow in Cleve & Grunow 1880
Nitzschia commutata Grunow in Cleve & Grunow 1880
Nitzschia commutatoides Lange-Bertalot 1987
Nitzschia dissipata (Kützing) Grunow 1862
Nitzschia dissipata* var. *media (Hantzsch) Grunow in Van Heurck 1881
Nitzschia dubia W. Smith 1853
Nitzschia dubia* var. *latestriata Østrup 1910
Nitzschia epithemiformis Lange-Bertalot 1980
Nitzschia epithemoides* var. *disputata (J.R. Carter) Lange-Bertalot 1987
Nitzschia filiformis (W. Smith) Van Heurck 1896
Nitzschia filiformis* var. *conferta (P.G. Richter) Lange-Bertalot 1987
Nitzschia fonticola (Grunow) Grunow in Van Heurck 1881
Nitzschia fontifuga Cholnoky 1962
Nitzschia frustulum (Kützing) Grunow in Cleve & Grunow 1880
Nitzschia frustulum* var. *subsalina Hustedt 1930
Nitzschia fruticosa Hustedt 1957
Nitzschia graciliformis Lange-Bertalot & Simonsen 1978
Nitzschia gracilis Hantzsch 1860
Nitzschia hantzschiana Rabenhorst 1860
Nitzschia harderi Hustedt in Brendemuhl 1949
Nitzschia heufleriana Grunow 1862
Nitzschia hybrida Grunow in Cleve & Grunow 1880
Nitzschia ignorata Krasske 1929
Nitzschia incognita Legler & Krasske 1940
Nitzschia inconspicua Grunow 1862
Nitzschia intermedia Hantzsch ex Cleve & Grunow 1880
Nitzschia kuetzingiana Hilse 1860
Nitzschia lacuum Lange-Bertalot 1980
Nitzschia liebethruthii Rabenhorst 1864
Nitzschia linearis (C. Agardh) W. Smith 1853
Nitzschia linearis* var. *subtilis Hustedt 1923
Nitzschia linearis* var. *tenuis (W. Smith) Grunow in Cleve & Grunow 1880
Nitzschia longissima (Brébisson in Kützing) Grunow 1862
Nitzschia lorenziana Grunow in Cleve & Möller 1879
Nitzschia macaronesica Lange-Bertalot 1993
Nitzschia macilenta W. Gregory in Greville 1859
Nitzschia microcephala Grunow 1880
Nitzschia minutissima W. Smith 1853
Nitzschia minutula Grunow in Van Heurck 1881
Nitzschia monguilloni Manguin 1942
Nitzschia nana Grunow in Van Heurck 1881
Nitzschia obtusa W. Smith 1853
Nitzschia palea (Kützing) W. Smith 1856
Nitzschia palea* var. *debilis (Kützing) Grunow in Cleve & Grunow 1880
Nitzschia palea* f. *dubia Manguin 1942
Nitzschia paleacea Grunow in Van Heurck 1881
Nitzschia paleaeformis Hustedt 1950
Nitzschia parvula W. Smith 1853
Nitzschia pecten Brun 1880
Nitzschia perminuta (Grunow in Van Heurck) Peragallo 1903
Nitzschia perspicua Cholnoky 1960

Nitzschia pseudoamphioxys Hustedt 1942
Nitzschia pseudofonticola Hustedt 1942
Nitzschia pumila Hustedt 1954
Nitzschia pusilla (Kützing) Lange-Bertalot 1976
Nitzschia recta Hantzsch ex Rabenhorst 1862
Nitzschia reversa W. Smith 1853
Nitzschia romana Grunow in Van Heurck 1881
Nitzschia rosenstockii Lange-Bertalot 1980
Nitzschia rostellata Hustedt 1956
Nitzschia ruttneri Hustedt 1937
Nitzschia scalpelliformis Grunow in Cleve & Grunow 1880
Nitzschia sigma (Kützing) W. Smith 1853
Nitzschia sigma* var. *rigidula (Peragallo & Peragallo) Grunow in Van Heurck 1881
Nitzschia sigmoidea (Nitzsch) W. Smith 1853
Nitzschia sinuata (Thwaites in Smith) Grunow in Cleve & Grunow 1880
Nitzschia sinuata* var. *delognei (Grunow in Van Heurck) Lange-Bertalot 1980
Nitzschia sociabilis Hustedt 1957
Nitzschia solita Hustedt 1953
Nitzschia stagnorum Rabenhorst 1848-1860
Nitzschia subacicularis Hustedt in Schmidt 1922
Nitzschia subcapitellata Hustedt 1939
Nitzschia sublinearis Hustedt in Schmidt 1921
Nitzschia subtilis (Kützing) Grunow in Cleve & Grunow 1880
Nitzschia subtubicola H. Germain 1981
Nitzschia suchlandtii Hustedt 1943
Nitzschia supralitorea Lange-Bertalot 1979
Nitzschia tabellaria (Grunow) Grunow in Cleve & Grunow 1880
Nitzschia terrestris (J.B. Petersen) Hustedt 1934
Nitzschia thermalis (Ehrenberg) Auerswald in Rabenhorst 1861-1882
Nitzschia thermalis* var. *intermedia Grunow in Van Heurck 1881
Nitzschia thermaloides Hustedt 1955
Nitzschia tubicola Grunow in Cleve & Grunow 1880
Nitzschia umbonata (Ehrenberg) Lange-Bertalot 1978
Nitzschia valdecostata Lange-Bertalot & Simonsen 1978
Nitzschia valdestriata Aleem & Hustedt 1951
Nitzschia vermicularis (Kützing) Hantzsch in Rabenhorst 1848-1860
Nitzschia vermicularis* var. *flexa (Schumann) Cleve-Euler 1952
Nitzschia vitrea G. Norman 1861
Nitzschia vitrea* var. *salinarum Grunow 1880
Nupela Vyverman & Compère 1991
Nupela impexiformis (Lange-Bertalot in Lange-Bertalot & Krammer) Lange-Bertalot 1999
Nupela lapidosa (Krasske) Lange-Bertalot 1999
Nupela silvahercynia (Lange-Bertalot) Lange-Bertalot in Lange-Bertalot & Metzeltin 1996
Orthosira Thwaites 1848
Orthoseira orichalcea W. Smith 1856
Orthoseira roeseana (Rabenhorst) O'Meara 1876
Paralia Heiberg 1863
Paralia sulcata (Ehrenberg) Cleve 1873
Paralia sulcata* var. *coronata (Ehrenberg) G.W. Andrews 1976
Parlibellus E.J. Cox 1988
Parlibellus crucicula (W. Smith) Witkowski, Lange-Bertalot & Metzeltin 2000
Parlibellus protracta (Grunow) Witkowski, Lange-Bertalot & Metzeltin 2000
Parlibellus protractus* var. *subcapitatus (Wislouch & V.S. Poretzky) Aboal 2003
Peronia Brébisson & Arnott ex Kitton 1868
Peronia fibula (Brébisson in Kützing) Ross 1956
Pinnularia Ehrenberg 1843
Pinnularia acorica Krammer & Metzeltin in Krammer 2000
Pinnularia acoricola Hustedt 1935
Pinnularia acrosphaeria (Brébisson) W. Smith 1853
Pinnularia acrosphaeria Rabenhorst 1853
Pinnularia acuminata W. Smith 1853
Pinnularia allorgei Manguin 1942
Pinnularia alpina* var. *alpina W. Smith 1853
Pinnularia angulosa Krammer 2000
Pinnularia angusta (Cleve) Krammer 1992
Pinnularia appendiculata (C. Agardh) Cleve 1895
Pinnularia appendiculata* f. *constricta Manguin 1942
Pinnularia bicapitata (Lagerstedt) Cleve 1891
Pinnularia biceps W. Gregory 1856
Pinnularia borealis Ehrenberg 1843
Pinnularia borealis* f. *elongata Manguin 1942
Pinnularia borealis* f. *rectangularis G.W.F. Carlson 1913
Pinnularia borealis* var. *subislandica Krammer 2000
Pinnularia brauniana (Grunow) Studnička 1888
Pinnularia braunii (Grunow in Van Heurck) Cleve 1895

Pinnularia braunii* var. *amphicephala (Ant. Mayer) Hustedt 1930
Pinnularia brebissonii (Kützing) Rabenhorst 1864
Pinnularia brebissonii* var. *angusta (Grunow) Rabenhorst 1864
Pinnularia brebissonii* var. *diminuta (Grunow in Van Heurck) Cleve 1895
Pinnularia brebissonii* var. *subproducta (Grunow in Van Heurck) Cleve-Euler 1932
Pinnularia brevicostata Cleve 1891
Pinnularia brevicostata* var. *intermedia Manguin 1942
Pinnularia caraccana Ehrenberg ex Rabenhorst 1853
Pinnularia dactylus Ehrenberg 1843
Pinnularia divergens W. Smith 1853
Pinnularia divergens* var. *undulata (Peragallo & Héribaud in Héribaud) Hustedt 1914
Pinnularia divergentissima (Grunow in Van Heurck) Cleve 1895
Pinnularia esox Ehrenberg 1843
Pinnularia exigua W. Gregory 1854
Pinnularia gentilis (Donkin) Cleve 1891
Pinnularia gibba Ehrenberg 1843
Pinnularia gibba* var. *linearis Hustedt 1930
Pinnularia gibba* var. *mesogongyla (Ehrenberg) Hustedt 1930
Pinnularia gibba* f. *minutissima Manguin 1942
Pinnularia gibba* var. *parva (Grunow) Frenguelli 1933
Pinnularia gibba* var. *sancta (Grunow ex Cleve) F. Meister 1932
Pinnularia gibba* var. *subundulata (Ant. Mayer ex Hustedt) Frenguelli 1933
Pinnularia globiceps W. Gregory 1856
Pinnularia gracilis Heiden & Kolbe 1928
Pinnularia hemiptera (Kützing) Rabenhorst 1853
Pinnularia hilseana C. Janisch in Hilse 1860
Pinnularia inflata (Kützing) Rabenhorst 1853
Pinnularia instabilis (A.W.F. Schmidt) Metzeltin in Metzeltin & Lange-Bertalot 1998
Pinnularia interrupta W. Smith 1853
Pinnularia interrupta* f. *minutissima (Hustedt) Hustedt 1930
Pinnularia interruptiformis Krammer 2000
Pinnularia joculata (Manguin) Krammer 2000
Pinnularia johnsonii W. Smith 1853
Pinnularia karelica Cleve 1891
Pinnularia kuetzingii Krammer 1992
Pinnularia lata (Brébisson) W. Smith 1853
Pinnularia legumen Ehrenberg 1843
Pinnularia lundii Hustedt 1954
Pinnularia lundii* var. *linearis Krammer 2000
Pinnularia major (Kützing) Rabenhorst 1853
Pinnularia major var. subacuta (Ehrenberg) Cleve 1895
Pinnularia mesolepta (Ehrenberg) W. Smith 1853
Pinnularia mesolepta* var. *producta (Grunow) Gutwinski 1891
Pinnularia mesolepta* var. *termes (Van Heurck) Mills 1934
Pinnularia metzeltinii Krammer 2000
Pinnularia microstauron (Ehrenberg) Cleve 1891
Pinnularia microstauron* var. *ambigua F. Meister 1912
Pinnularia microstauron* f. *minutissima Manguin 1942
Pinnularia microstauron* var. *rostrata Krammer 2000
Pinnularia nobilis (Ehrenberg) Ehrenberg 1843
Pinnularia nodosa (Ehrenberg) W. Smith 1856
Pinnularia obscura Krasske 1932
Pinnularia parva* f. *interrupta J.B. Petersen 1928
Pinnularia perirrorata Krammer 2000
Pinnularia polyonca (Brébisson in Kützing) W. Smith 1856
Pinnularia pseudogibba Krammer 1992
Pinnularia quadrifasciata (Ehrenberg) Ehrenberg 1854
Pinnularia rabenhorstii (Grunow) Krammer 2000
Pinnularia rhombarea* var. *biundulata (O. Müller) Krammer 2000
Pinnularia rhomboelliptica Krammer 2000
Pinnularia rhomboelliptica* var. *inflata Krammer 2000
Pinnularia rivularis Hustedt 1935
Pinnularia rupestris Hantzsch in Rabenhorst 1861
Pinnularia schroederi (Hustedt) Cholnoky 1959
Pinnularia septentrionalis Krammer 2000
Pinnularia similis Hustedt 1937
Pinnularia stauroptera (Grunow) Rabenhorst 1864
Pinnularia stauroptera* var. *interrupta Cleve 1895
Pinnularia stomatophora (Grunow in Schmidt) Cleve 1895
Pinnularia streptoraphe Cleve 1891
Pinnularia streptoraphe* f. *minor Manguin 1942
Pinnularia subcapitata W. Gregory 1856
Pinnularia subcapitata* var. *appendiculata Willi Krieger 1930
Pinnularia subcapitata* var. *azorica Holmboe 1901
Pinnularia subcapitata* var. *elongata Krammer 1992

Pinnularia subcapitata* var. *hybrida (Grunow in Van Heurck) Frenguelli 1933
Pinnularia subcapitata* f. *lata Manguin 1942
Pinnularia subcapitata* var. *paucistriata (Grunow in Van Heurck) Cleve 1895
Pinnularia subcapitata* var. *stauroneiformis (Van Heurck) O. Müller 1898
Pinnularia subcapitata* f. *typica J.B. Petersen 1928
Pinnularia subcapitata* f. *undulata O. Müller ex Hustedt 1930
Pinnularia subgibba Krammer 1992
Pinnularia subgibba* var. *hustedtii Krammer 1992
Pinnularia subgigas Krammer 2000
Pinnularia subrostrata (A. Cleve) Cleve-Euler 1955
Pinnularia subsolaris (Grunow) Cleve 1895
Pinnularia subsolaris* f. *mutabilis Manguin 1942
Pinnularia sudetica (Hilse in Rabenhorst) M. Peragallo 1903
Pinnularia superdivergentissima Chaumont & Germain 1976
Pinnularia tabellaria Ehrenberg 1843
Pinnularia tirolensis* var. *julma Krammer 2000
Pinnularia viridiformis Krammer 1992
Pinnularia viridis (Nitzsch) Ehrenberg 1843
Pinnularia viridis* var. *commutata (Grunow in Schmidt) Cleve 1895
Pinnularia viridis* var. *fallax Cleve 1895
Pinnularia viridis* var. *intermedia sensu Cleve-Euler 1932
Placoneis Mereschkowsky 1903
Placoneis anglica (Ralfs in Pritchard) R.L. Lowe in Johansen et al. 2004
Placoneis anglophila (Lange-Bertalot) Lange-Bertalot in Metzeltin, Lange-Bertalot & García-Rodríguez 2005
Placoneis clementioides (Hustedt) E.J. Cox 1987
Placoneis clementis (Grunow) E.J. Cox 1987
Placoneis dicephala Mereschkowsky 1903
Placoneis elginensis (W. Gregory) E.J. Cox 1987
Placoneis elginensis* f. *exigua (W. Gregory) Bukhtiyarova 1995
Placoneis gastrum (Ehrenberg) Mereschkowsky 1903
Placoneis neglecta R.L. Lowe in Johansen et al. 2004
Placoneis placentula Heinzerling 1908
Placoneis porifera (Hustedt) E.J. Cox 2003
Planothidium Round & Bukhtiyarova 1996
Planothidium biporomum (M.H. Hohn & Hellerman) Lange-Bertalot 1999
Planothidium calcar (Cleve) Round et Bukhtiyarova 1996
Planothidium conspicuum (Ant. Mayer) E. Morales 2006
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Planothidium delicatulum (Kützing) Round & Bukhtiyarova 1996
Planothidium distinctum (Messikommer) Lange-Bertalot 1999
Planothidium dubium (Grunow) Round et Bukhtiyarova 1996
Planothidium ellipticum (Cleve) Edlund in Edlund, Soninkhishig, D.M. Williams & Stoermer 2001
Planothidium engelbrechtii (Cholnoky) Round & Bukhtiyarova 1996
Planothidium frequentissimum (Lange-Bertalot in Krammer & Lange-Bertalot) Lange-Bertalot 1999
Planothidium granum (M.H. Hohn & Hellerman) Lange-Bertalot 1999
Planothidium hauckianum (Grunow) Round & Bukhtiyarova 1996
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot 1999
Planothidium oestrupii (Cleve-Euler) Round & Bukhtiyarova 1996
Planothidium peragallii (Brun & Héribaud) Round & Bukhtiyarova 1996
Planothidium rostratum (Østrup) Lange-Bertalot 1999
Platessa Lange-Bertalot in Krammer & Lange-Bertalot 2004
Platessa hustedtii (Krasske) Lange-Bertalot in Krammer & Lange-Bertalot 2004
Pleurosigma W. Smith 1852
Pleurosigma angulatum sensu W. Smith emend Sterrenburg 1991
Pleurosigma elongatum W. Smith 1852
Pleurosigma spencerii* var. *smithii Grunow in Cleve & Grunow 1880
Pleurosigma spencerii* var. *splendida (Ehrenberg) Van Heurck
Pleurosigma strigosum W. Smith 1852
Pleurosira (Meneghini) V.B.A. Trevisan 1848
Pleurosira laevis (Ehrenberg) Compère 1982
Prestauroneis Bruder & Medlin 2008
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Psammodictyon D.G. Mann in Round, Crawford & Mann 1990
Psammodictyon mediterraneum (Hustedt in A.W.F. Schmidt) D.G. Mann 1990
Psammothidium Bukhtiyarova & Round 1996
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Psammothidium chlidanos (M.H. Hohn & Hellerman) Lange-Bertalot 1999
Psammothidium kryophilum (J.B. Petersen) E. Reichardt 2004
Psammothidium marginulatum (Grunow) Bukhtiyarova & Round 1996
Psammothidium sacculum (J.R. Carter) Bukhtiyarova in Bukhtiyarova & Round 1996
Psammothidium semiapertum (Hustedt) Aboal 2003
Psammothidium subatomoides (Hustedt) Bukhtiyarova & Round 1996
Psammothidium ventralis (Krasske) Bukhtiyarova & Round 1996
Psammosynedra Round 1993
Psammosynedra closterioides (Grunow) Round 1993

PSEUDO-EUNOTIA Grunow in Van Heurck 1881
Pseudoeunotia lunaris (Ehrenberg) De Toni 1892
PSEUDO-NITZSCHIA H. Peragallo in Peragallo & Peragallo 1900
Pseudonitzschia seriata (Cleve) Peragallo & Peragallo 1899
PSEUDOSTAUROSIRA D.M. Williams & Round 1988
Pseudostaurosira brevistriata (Grunow in Van Heurck) D.M. Williams & Round 1987
Pseudostaurosira parasitica (W. Smith) E. Morales 2003
Pseudostaurosira parasitica* var. *subconstricta (Grunow) E. Morales 2003
Pseudostaurosira pseudoconstruens (Marciniak) D.M. Williams & Round 1987
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Pseudostaurosira zeilleri (Héribaud) D.M. Williams & Round 1987
PUNCTASTRIATA D.M. Williams & F.E. Round 1988
Punctastriata lancettula (Schumann) P.B. Hamilton & P.A. Siver 2008
PUNCTICULATA Håkansson 2002
Puncticulata bodanica (Grunow in Schneider) Håkansson 2002
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REIMERIA Kociolek & Stoermer 1987
Reimeria sinuata (W. Gregory) Kociolek & Stoermer emend Sala, Guerrero & Ferrario 1993
Reimeria sinuata* f. *ovata (Hustedt) Hartley 1996
Reimeria uniseriata Sala, Guerrero & Ferrario 1993
RHOICOSPHENIA Grunow 1860
Rhoicosphenia abbreviata (C. Agardh) Lange-Bertalot 1980
Rhoicosphenia curvata (Kützing) Grunow 1860
RHOPALODIA O. Müller 1895
Rhopalodia gibba (Ehrenberg) O. Müller1895
Rhopalodia gibba* var. *minuta Krammer 1987
Rhopalodia gibba* var. *parallela (Grunow) H. Peragallo & Peragallo 1900
Rhopalodia gibba* var. *ventricosa (Kützing) Ant. Mayer 1913
Rhopalodia gibberula (Ehrenberg) O. Müller 1895
Rhopalodia gibberula* var. *producta (Grunow) Cleve-Euler 1952
Rhopalodia gibberula* var. *vanheurckii O. Müller 1900
Rhopalodia musculus (Kützing) O. Müller 1900
Rhopalodia operculata (C. Agardh) Håkansson 1979
Rhopalodia rupestris (W. Smith) Krammer 1987
ROSSITHIDIUM Round & Bukhtiyarova 1996
Rossithidium pusillum (Grunow) Round & Bukhtiyarova in Bukhtiyarova 2008
SCOLIONEIS D.G. Mann in Round, Crawford & Mann 1990
Scolioneis tumida (Brébisson ex Küzing) Mann in Round, Crawford & Mann 1990
SELLAPHORA Mereschkowsky 1902
Sellaphora americana (Ehrenberg) D.G. Mann 1989
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Simonsenia delognei (Grunow) Lange-Bertalot 1979b
SKELETONEMA Greville 1865
Skeletonema costatum (Greville) Cleve 1873
Skeletonema subsalsum (A. Cleve-Euler) Bethge 1928
STAUROFORMA Flower, Jones & Round 1996
Stauroforma exiguiformis (Lange-Bertalot) Flower, Jones & Round 1996
STAURONEIS Ehrenberg 1843
Stauroneis acuta W. Smith 1853
Stauroneis amphicephala Kützing 1844
Stauroneis anceps Ehrenberg 1843
Stauroneis anceps* f. *gracilis (Ehrenberg) Hustedt 1930
Stauroneis anceps* var. *hyalina Peragallo & Brun in Héribaud 1893
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Stauroneis salina W. Smith 1853
Stauroneis smithii Grunow 1860
Stauroneis smithii* var. *borgei (Manguin in Allorge & Manguin) Hustedt 1959
Stauroneis smithii* var. *incisa Pantocsek 1902
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Staurosira construens Ehrenberg 1843
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Staurosirella pinnata (Ehrenberg) D.M. Williams & Round 1987
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Stenopterobia curvula (W. Smith) Krammer 1987
Stenopterobia delicatissima (F.W. Lewis) Van Heurck 1896
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Stenopterobia sigmatella (W. Gregory) Ross in Hartley 1986
STEPHANODISCUS Ehrenberg 1845
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Stephanodiscus hantzschii* var. *pusilla Grunow in Cleve & Grunow 1880
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Surirella angustata Hustedt 1930
Surirella apiculata W. Smith 1856
Surirella biseriata Brébisson in Brébisson & Godey 1835
Surirella biseriata* f. *amphioxys (W. Smith) Hustedt 1911
Surirella biseriata* var. *bifrons (Ehrenberg; Ehrenberg) Hustedt 1911
Surirella biseriata* var. *minor Brébisson ex W. Smith Collection
Surirella capronii Brébisson & Kitton 1869
Surirella constricta W. Smith 1851
Surirella delicatissima* f. *tenuissima Manguin 1942
Surirella elegans Ehrenberg 1843
Surirella biseriata* var. *turgida (W. Smith) Cleve-Euler 1952
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Surirella linearis W. Smith 1853
Surirella linearis* var. *constricta Grunow 1862
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Surirella minuta Brébisson 1838
Surirella moelleriana Grunow in Schmidt 1875
Surirella nana Cleve-Euler 1915
Surirella nervosa (A.W.F. Schmidt in Schmidt) Ant. Mayer 1913
Surirella oblonga Ehrenberg 1843
Surirella ovalis Brébisson 1838
Surirella ovalis* var. *apiculata O. Müller 1903
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Surirella tenera W. Gregory 1856
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Synedra Ehrenberg 1830
Synedra acus* var. *angustissima (Grunow) Van Heurck 1885
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Synedra polymorpha (Pantocsek & Grunow) H.-J. Schrader 1969
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Synedra tenuis Kützing 1844
Synedra torta No authors mentioned
Synedra ulna* var. *bicurvata (Biene ex Rabenhorst) Grunow in Van Heurck 1881
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Synedra vitrea Kützing 1844
Tabellaria Ehrenberg ex Kützing 1844
Tabellaria fenestrata (Lyngbye) Kützing 1844
Tabellaria fenestrata* f. *intermedia (Grunow) Skabichevskii 1960
Tabellaria flocculosa (Roth) Knudson 1952
Tabellaria ventricosa Kützing 1844
Tabularia (Kützing) D.M. Williams & Round 1986
Tabularia affinis (Kützing) Snoeijs 1992
Tabularia fasciculata (C. Agardh) D.M. Williams & Round 1986
Tabularia tabulata (C. Agardh) Snoeijs 1992
Tetracyclus Ralfs 1843
Tetracyclus braunii Grunow 1862
Thalassiosira Cleve 1873
Thalassiosira decipiens (Grunow) E.G. Jørgensen 1905
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Tryblionella calida (Grunow in Cleve & Grunow) D.G. Mann 1990
Tryblionella compressa (Bailey) Poulin 1990
Tryblionella constricta (Kützing) Poulin 1990
Tryblionella debilis Arnott ex O'Meara 1873
Tryblionella gracilis W. Smith 1853
Tryblionella granulata (Grunow) D.G. Mann in Round, Crawford & Mann 1990
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Tryblionella levidensis W. Smith 1856
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Tryblionella scalaris (Ehrenberg) Siver & P.B. Hamilton 2005
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Ulnaria ulna* var. *amphirhynchus (Ehrenberg) Aboal 2003
Ulnaria ulna* var. *spathulifera (Grunow in Van Heurck) Aboal 2003
Ulnaria ulna* var. *splendens (Kützing) Aboal 2003
Ulnaria ulna* var. *subaequalis (Grunow in Van Heurck) Aboal 2003
UROSOLENIA Round & Crawford in Round, Crawford & Mann 1990
Urosolenia eriensis (H.L. Smith) Round & Crawford in Round, Crawford & Mann 1990
Urosolenia longiseta (Zacharias) Edlund & Stoermer 1993
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Chapter 3

DIATOMS IN PORTUGUESE FRESHWATERS: AN ICONOGRAPHIC ATLAS

3 Diatoms in Portuguese freshwaters: an iconographic atlas

Abstract

This iconographic guide is being produced in order to serve as a practical basis for those who wish to study freshwater diatoms from Portugal, especially the professionals who will be in charge of the routine monitoring of the water quality according to the recent implementation of the Water Framework Directive ((WFD, Directive 2000/60/EC) in the country.

This guide is based on light and scanning electron microscopy investigation of the diatoms present in epilithic samples collected in the years 2006 and 2007 from watercourses throughout the whole country (363 sampling sites) and from 18 reservoirs (seasonally sampled by the National Water Institute team in 2006).

The purpose of this Atlas is to serve as a practical guide for the identification of the common diatom species found in Portuguese watercourses, and not as an exhaustive flora. Therefore, only the species with abundance above 5% in at least one inventory or that are of special interest, are illustrated, in a total of 295 taxa belonging to 65 genera. For each species, a series of light microscope micrographs is included; for the more interesting species or those that pose taxonomical difficulties, scanning electron micrographs are also provided with the aim to illustrate their most important ultrastructural characteristics. The information about the basionym, the most commonly used nomenclatural synonyms, morphometry, ecological preferences (for the new records for the Iberian Peninsula) as reconstructed from field observations and SPI pollution sensitivity (S) and stenoecy degree (V) values from OMNIDIA v. 5.3 are also supplied.

3.1 Introduction

Diatoms are among the most recognizable groups of major eukaryotic algae due to their peculiar silicified cell walls (frustules) that consist of two overlapping thecae formed by a valve and hoop-like or segmental girdle bands (SIMS et al. 2006). Detailed information about the morphological and ultrastructural features of diatoms is presented in several studies (e.g. ROUND et al. 1990). They are a widespread group of algae, being major constituents of benthic and planktonic algal communities worldwide, in terrestrial, freshwater and marine habitats (MANN & DROOP 1996). There is still no accurate estimation on the number of species (STOERMER & SMOL 1999) nevertheless MANN & DROOP (1996) suggest that a value not less than $2x10^5$ would be reachable, taking into account the application of a narrower species concept and also the new discoveries from understudied areas and habitats, like tropical regions and marine benthos from the subtidal zone, what would make diatoms as the most species-rich group of algae.

Diatoms belong to the pigmented heterokont algae, characterized by the presence of chlorophylls *a* and *c* and two heterodynamic flagella in the spermatozoids of the oogamous genera (the apically inserted flagellum bears tripartite mastigonemes, whereas the laterally inserted one is smooth). In diatoms only the spermatozoids of the oogamous genera are flagellated, although they lack the smooth posterior flagellum and the second basal body, nevertheless they still belong to the heterokont algae due to the shared plastid ultrastructure and pigment composition (MEDLIN & KACZMARSKA 2004).

It is considered unlikely that diatoms existed before the Permian-Triassic boundary (about 250 Ma) (MEDLIN et al. 1997) and their origin has been subject of speculations for long, with several hypotheses being presented; nevertheless it is considered that a scaly ancestor likely existed at some point in their phylogeny due to the presence of scales on the reproductive cells of diatoms (MEDLIN et al. 1997).

The classification of diatoms has been for long a dilemma for those interested in the subject, with several hypotheses being presented along times, as described by WILLIAMS (2007). These classifications were based on different criteria, from the first morphological approaches based on light microscopy observations, the ones based on ultrastructural features studied under scanning electron microscopy until the recent advances by molecular approaches. Two landmark classifications, based in the molecular phylogeny of diatoms are proposed by MANN in ADL et al. (2005) and by MEDLIN & KACZMARSKA (2004) and consist in a single branching diagram with four nodes: the first two nodes consist in two new subdivisions: Coscinodiscophytina and Bacillariophytina, the third and fourth nodes correspond to the classes Mediophyceae and Bacillariophyceae within the subdivision Bacillariophytina (WILLIAMS 2007). In terms of morphological symmetry, the Coscinodiscophytina includes the radial centrics, the class Mediophyceae includes the bipolar centrics and the radial Thalassiosirales and the class Bacillariophyceae comprises the pennates (MEDLIN & KACZMARSKA 2004). Although this effort to perform a phylogenetic classification included cytological and morphological data to support the major molecular clades of the diatoms, it has been subject of controversy. According to WILLIAMS & KOCIOLEK (2007), the classifications proposed by MEDLIN & KACZMARSKA (2004) and MANN in ADL et al. (2005) should be rejected since they explicitly recognize the presence of non-monophyletic groups (Coscinodiscophytina and Mediophyceae). Nevertheless, MEDLIN (2010) argues that these critics are not well supported and that the Coscinodiscophytina and Mediophyceae are indeed monophyletic, as presented in works published by other researchers.

In aquatic environments, diatoms are subject to numerous environmental factors that influence the species diversity and composition of their assemblages. Different species-specific requirements on environmental conditions have been recognized for many diatom species, which made them a promising tool for the monitoring of water quality. Diatoms have therefore proved to be good indicators of several stressors such as organic contamination, lake acidification, climate change and nutrient concentrations (STEVENSON et al. 2008). And it is clear that diatoms can be more precise indicators of some physico-chemical conditions than one time sampling and measurement of those conditions (STEVENSON 2006).

Diatoms have been widely used to assess the ecological status around the world (WATANABE et al. 1986; TAYLOR et al. 2007; LAVOIE et al. 2008) and in European rivers (KELLY & WHITTON 1995; PRYGIEL & COSTE 1999; ROTT et al. 2003; GOMÀ et al. 2005; HLÚBIKOVÁ et al. 2007; BLANCO et al. 2008), since they are being used in most EU Member States (Portugal included) as cost-effective proxies for phytobenthos-based water quality assessment (INAG 2008; KELLY et al. 2009). In Portugal, several studies using diatoms as water quality indicators in rivers have also been performed, mainly in the central region of the country (ALMEIDA 1998, 2001; ALMEIDA & GIL 2001; NUNES et al. 2003; FEIO et al. 2007). Nevertheless, these studies were performed using the indices developed in other European regions, which are not specifically adapted to the ecological preferences of the Portuguese diatom flora.

It has been claimed for long time that many diatom species are widely distributed within a climatic zone or even cosmopolitan. This statement could lead to the conclusions that local or national studies of diatom biodiversity are not a priority, the same floras could be used worldwide and that diatom biogeography is worth studying only on a global scale or scarcely differs from diatom ecology (each species would occur everywhere its own ecological tolerances are met and where it is competitively superior). Therefore, conservation would be unlikely an important issue on diatoms. Nevertheless, authors like MANN & DROOP (1996) have proved the contrary, and according to these authors, the perception of diversity, the detection of biogeographical patterns and the assessment of rarity are directly linked with taxonomy. Consequently, fine-grained taxonomy can reveal the unique diatom species present in many regions that otherwise can be overlooked and can thus increase the precision of ecological monitoring (MANN & DROOP 1996).

Moreover, the continuous splitting of diatom species complexes due to the use of innovative techniques, such as the scanning electron microscopy and, more recently, molecular techniques, highly increases the number of species. This increase seriously complicates the capacity of keeping updated with the new findings at a global scale, making essential to produce local floras. This trend is already being followed in some regions, i.e. Duero basin in Spain (BLANCO et al. 2010), Alpes-Maritimes and Region Province Alpes-Côte d'Azur in France (ECTOR & HLÚBIKOVÁ 2010), Eastern Canada (LAVOIE et al. 2008) and South Africa (TAYLOR et al. 2007). Also ROTT et al. (2003), among the requirements for the development of highly predictive diatom based river quality monitoring systems, emphasize the need of an harmonised and easily applicable diatom identification system.

In Portugal, the study of freshwater diatoms started in the middle of the XIXth century by EHRENBERG (1845), and was followed by the contributions of botanists such as ZIMMERMANN (1906, 1909, 1910, 1914, 1915, 1917), CARVALHO (1913), SILVA (1950a, 1950b). Afterwards, several publications included diatoms as a component of the total phytoplankton (i.e. NAUWERCK 1959, 1962; OLIVEIRA 1984, 1985, 1987; OLIVEIRA et al. 1985, 1989). Lately, several publications about taxonomy, ecology and use of diatoms as bioindicators have been produced mainly by researchers from the University of Aveiro, essentially focusing in the central region of the country (ALMEIDA 1998, 2001; ALMEIDA & GIL 2000, 2001; ALMEIDA et al. 2010; CALADO 1990; GIL 1988, 1989, 1993; GIL et al. 1989-1990, 1991; GIL & ALMEIDA 1993; NUNES et al. 2003; NUNES 2007; RINO & GIL 1989). Nevertheless, these deep studies

cover a confined geographic area and there are still vast areas of the territory that remain completely unexplored, as can be seen in the Figure 2.8 (map with the number of diatom records per municipality).

With the implementation of the Water Framework Directive (WFD, Directive 2000/60/EC) in the country an emphasis has been done on the study of freshwater diatoms in Portugal, nevertheless the only published works with results for the whole country are INAG (2008) and MORAIS et al. (2009a, 2009b). These works consist in a protocol for the sampling and analysis (including a taxa list) and in the validation of the river typology based on diatoms, therefore there is still a lack of knowledge about the diversity, morphology and ecology of a great part of the freshwater diatoms from the country.

The present work aims to fulfil some of the lacks previously mentioned, concerning the knowledge about freshwater diatoms in Portugal. It intends to characterize the most abundant and frequent diatom species from Mainland Portugal in terms of their morphology, morphometry and ultrastructure by means of light and scanning electron microscopy. Furthermore, since the ecology of each taxon is crucial in the application of diatoms for monitoring purposes, the ecological preferences of the taxa that are new citations for the Iberian Peninsula are presented for several parameters, i.e. conductivity, pH, oxygen and nutrients such as nitrates, nitrites, soluble reactive phosphorus and total organic carbon TOC.

3.2 Materials and methods

3.2.1 Sampling

The **river epilithic diatoms** were sampled in spring and summer 2006 and 2007 from 363 sites in watercourses distributed throughout the whole country (Table 3.1, Figure 3.1 and Figure 3.2), covering the whole range of organic pollution, from reference sites without anthropogenically induced pollution to highly polluted (contaminated) sites. The sampling sites correspond to part of those previously selected for the Water Framework Directive (WFD, Directive 2000/60/EC) application (Morais 2009a), due to the fact that there is more information already available about them, namely about the land use and chemical data.

At each sampling site, water samples for chemical analysis were collected from lotic zones, and environmental variables such as temperature (ºC), pH, dissolved oxygen (mg L^{-1}), oxygen saturation (%) and conductivity (µS cm^{-1}) were measured *in situ* with portable instruments calibrated in the field.

Epilithic diatoms were collected from natural substrata (stones) following the national protocol (INAG 2008) and European norms (KELLY et al. 1998; AFNOR 2003; European Committee for Standardization 2003) and preserved with formaldehyde solution (4% v/v) immediately after sampling.

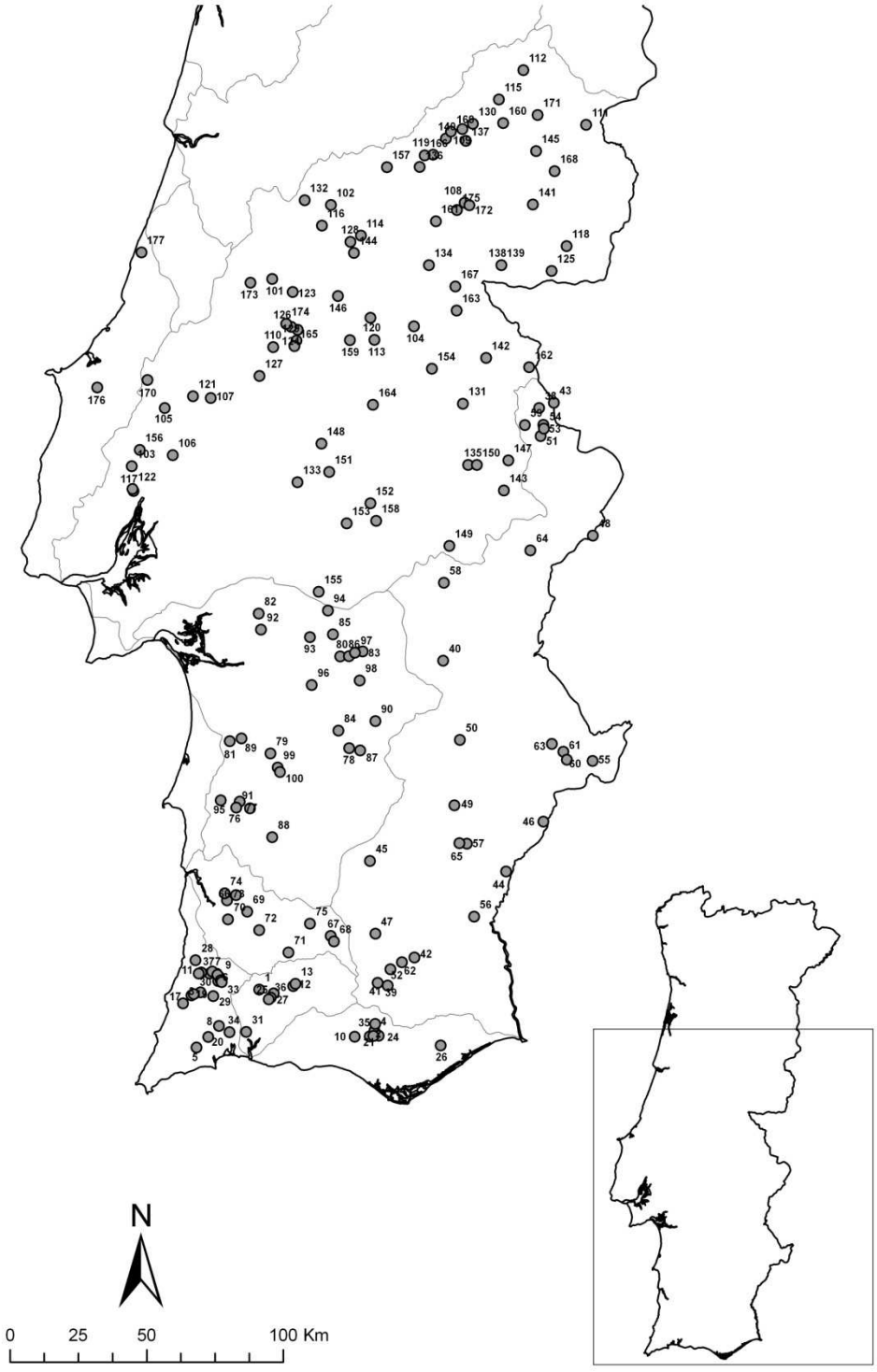

Figure 3.1 Map with the location of the sites sampled in 2006 in the South of Portugal. The numbers correspond to the identification number (ID) presented in Table 3.1.

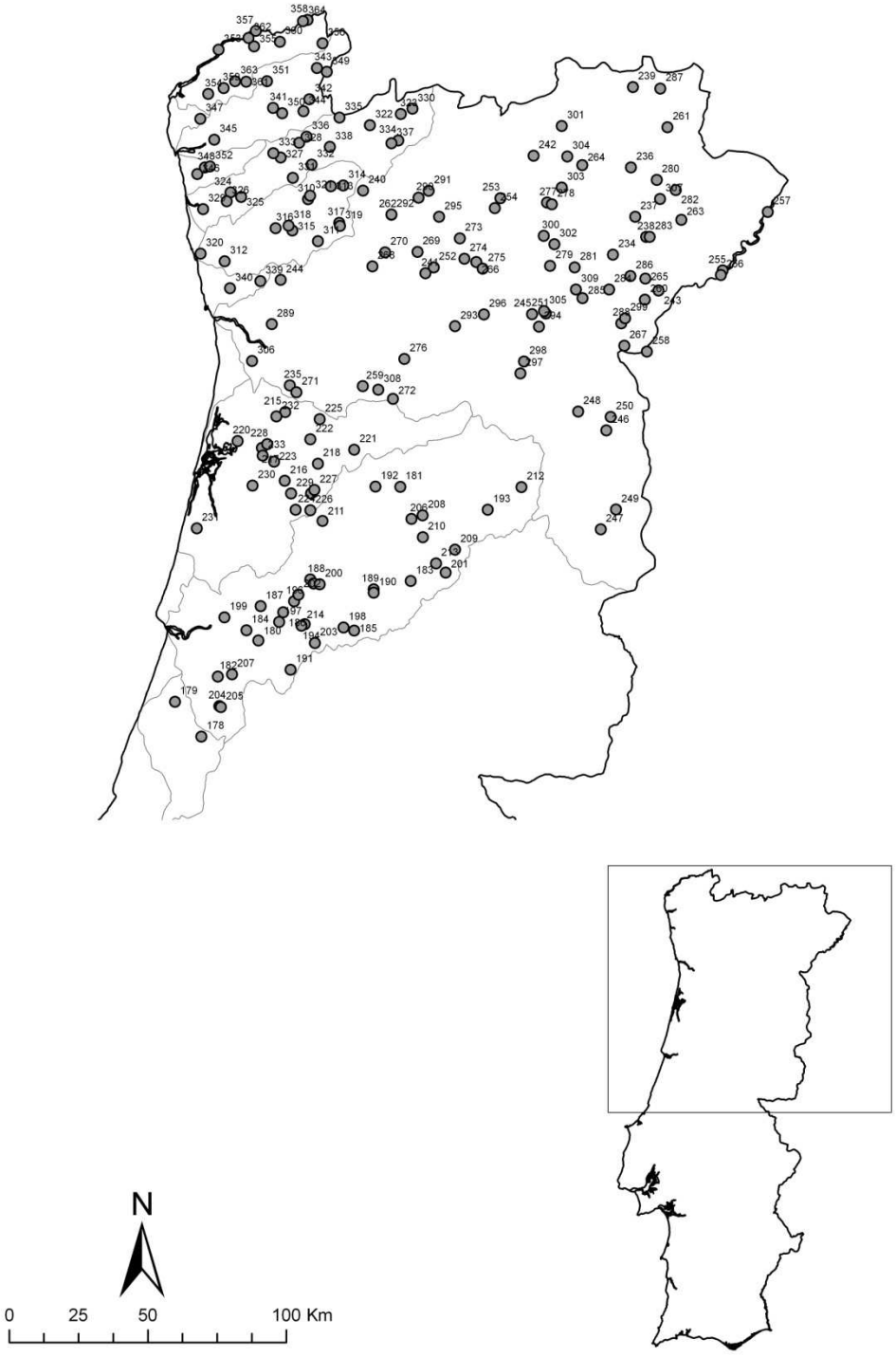

Figure 3.2 Map with the location of the sites sampled in 2007 in the Centre and North of Portugal. The numbers correspond to the identification number (ID) presented in Table 3.1.

Table 3.1 Characteristics of sampling sites. Coordinates refer to the datum Lisboa. The identification number (ID) refers to the identification of the sites presented in the distribution maps (Figure 3.1 andFigure 3.2).

Site	Watercourse (Main Basin)	Sampling date	UTM X	UTM Y	ID
Água Velha	Água Velha Creek (Ribeiras do Algarve)	05/12/2006	182185	44033	13
Alferce	Monchique Stream (Ribeiras do Algarve)	17/04/2006	168987.2	41944.1	1
Algibre	Algibre Stream (Ribeiras do Algarve)	17/04/2006	209369	24883	2
Arroio de Baixo	Seixe Stream (Ribeiras do Algarve)	05/12/2006	153941	45093	16
Azenha	Alfambras Stream (Ribeiras do Algarve)	15/04/2006	141061	36973	3
Benémola Jusante	Fonte Menalva Stream (Ribeiras do Algarve)	24/04/2006	211340	25965.9	4
Bensafrim	Fonte do Maranhão Stream (Ribeiras do Algarve)	14/04/2006	145983.8	20819.1	5
Besteiros	Seixe Stream (Ribeiras do Algarve)	16/04/2006	153448	47698	6
Besteiros Jusante	Seixe Stream (Ribeiras do Algarve)	16/04/2006	150760	47838	7
Bravura	Odiáxere Stream (Ribeiras do Algarve)	14/04/2006	150300.3	24646.2	8
Cabeço	Seixe Stream (Ribeiras do Algarve)	15/04/2006	154464.9	46542.8	9
Cerca dos Pomares	Aljezur Stream (Ribeiras do Algarve)	04/12/2006	144152	39860	17
Espargal	Algibre Stream (Ribeiras do Algarve)	17/04/2006	203902	24728	10
Fonte Benémola	Fonte Menalva Stream (Ribeiras do Algarve)	24/04/2006	211109	26849	21
Foz de Besteiros	Seixe Stream (Ribeiras do Algarve)	16/04/2006	153724	47377	22
Foz do Arroio	Seixe Stream (Ribeiras do Algarve)	04/12/2006	154452	46530	15
Foz do Carvalhoso	Seixe Stream (Ribeiras do Algarve)	15/04/2006	154897	45352	23
Loulé	Mercês Stream (Ribeiras do Algarve)	06/05/2006	212734	25119	24
Moinho do Bispo	Cerca Stream (Ribeiras do Algarve)	04/12/2006	147443	41004	18
Monte Branco	Odelouca Stream (Ribeiras do Algarve)	17/04/2006	174229	40584	25
Morenos	Corte Creek (Ribeiras do Algarve)	11/03/2006	235409	21531	26
Nora	Odelouca Stream (Ribeiras do Algarve)	17/04/2006	173187.1	39062.4	27
Oleiros	Seca Stream (Ribeiras do Algarve)	16/04/2006	145660	52710	28
Parcanhão	Perna Seca Stream (Ribeiras do Algarve)	05/12/2006	181371	43202	12
Passil	Aljezur Stream (Ribeiras do Algarve)	04/12/2006	152120	39582	19
Passil	Aljezur Stream (Ribeiras do Algarve)	15/04/2006	152118	39572	29
Pereira	Arão Stream (Ribeiras do Algarve)	06/05/2006	154236	28722	20
Pêro Negro	Cerca Stream (Ribeiras do Algarve)	15/04/2006	145023	40318	30
Porto de Lagos	Boina Stream (Ribeiras do Algarve)	17/04/2006	164195.4	26548.5	31
Salir	Salgada Stream (Ribeiras do Algarve)	24/04/2006	211433	29476	32

Site	Watercourse (Main Basin)	Sampling date	UTM X	UTM Y	ID
Selão	Seixe Stream (Ribeiras do Algarve)	16/04/2006	155242.5	44750.4	33
Senhora do Verde	Farelo Stream (Ribeiras do Algarve)	14/04/2006	158039	26438.8	34
Tôr	Algibre Stream (Ribeiras do Algarve)	17/04/2006	210790	25078.4	35
Vale de Agoia	Seixe Stream (Ribeiras do Algarve)	04/12/2006	151795	48593	14
Várzea de Romba	Odelouca Stream (Ribeiras do Algarve)	17/04/2006	172446.1	38355.8	36
Zambujeira	Seixe Stream (Ribeiras do Algarve)	16/04/2006	146871.2	47851.8	37
Zambujeira de Baixo	Seixe Stream (Ribeiras do Algarve)	05/12/2006	147784	48185	11
Alegrete	Arronches Stream (Guadiana)	24/05/2006	271408	254215	38
Ameixial	Vascãozinho Stream (Guadiana)	24/04/2006	215972	43459	39
Azambuja	Azambuja Stream (Guadiana)	15/05/2006	236315.3	161935	40
Azinhal de Mouros	Vascão Stream (Guadiana)	24/04/2006	212366	44473	41
Barranco	Vascão Stream (Guadiana)	24/04/2006	225766	53647	42
Cabroeira de Baixo	Xévora River (Guadiana)	24/05/2006	276785.3	256097.9	43
Corte do Pinto	Alcaides Creek (Guadiana)	25/04/2006	259367	85065	44
Entradas	Terges Stream (Guadiana)	15/05/2006	209498	88877	45
Ficalho	Vidigão Stream (Guadiana)	27/04/2006	272954	103261	46
Gorazes	Oeiras Stream (Guadiana)	25/04/2006	211499	62391	47
Guadiana-Caia	Guadiana River (Guadiana)	20/06/2006	291112	207642	48
Machadinho	Guadiana River (Guadiana)	18/05/2006	240360	109227	49
Marmelar	Marmelar Stream (Guadiana)	27/04/2006	242433.7	133041.4	50
Monte da Laje	Arronches Stream (Guadiana)	24/05/2006	271932	243901	51
Monte dos Corvos	Vascão Stream (Guadiana)	24/04/2006	216945.2	49333.1	52
Mosteiros	Arronches Stream (Guadiana)	24/05/2006	272961	248080	53
Mosteiros Jusante	Arronches Stream (Guadiana)	24/05/2006	273109.1	246686.6	54
Murtigão	Murtigão Stream (Guadiana)	27/04/2006	290993	125403	55
Penha de Águia	Guadiana River (Guadiana)	18/05/2006	247600.8	68628.3	56
Pulo do Lobo	Limas Stream (Guadiana)	27/04/2006	244949	95225	57
Queimado	Pardiela Stream (Guadiana)	25/05/2006	236531	190409	58
Ribeira da Fadagosa	Fadagosa Stream (Guadiana)	24/05/2006	266185.4	247982.2	59
Safara	Safara Stream (Guadiana)	27/04/2006	280310.1	128732.2	60
Safareja	Safareja Stream (Guadiana)	27/04/2006	281532.6	125845.6	61
Santa Cruz	Vascão Stream (Guadiana)	24/04/2006	221215	51904.4	62
Santo Amador	Vale de Vinagre Creek (Guadiana)	27/04/2006	276068.7	131621	63

Site	Watercourse (Main Basin)	Sampling date	UTM X	UTM Y	ID
São Romão	São Romão Stream (Guadiana)	02/06/2006	268232	202184	64
Terges	Terges River (Guadiana)	25/04/2006	242230	95368	65
Afluente do Torgal	Capelinha Stream (Mira)	09/05/2006	160452	76429	66
Gomes Aires ETAR	Mira River (Mira)	25/04/2006	195090.1	61495.5	67
Gomes Aires Montante	Mira River (Mira)	25/04/2006	196317	59552.5	68
Luzianes	Monte Novo Stream (Mira)	09/05/2006	164573	70372	69
Mira-Cola	Mira River (Mira)	25/04/2006	187577	66057	75
Odemira	Mira River (Mira)	09/05/2006	157574.1	67614.8	70
Rio Torto	Torto River (Mira)	25/04/2006	179704	55549	71
Santa Clara	Luzianes Stream (Mira)	09/05/2006	168920.9	63679.7	72
Torgal Jusante	Torgal Stream (Mira)	09/05/2006	157180	74568	73
Torgal Montante	Torgal Stream (Mira)	09/05/2006	156301	77050	74
Abela Jusante	Martinhenos Creek (Sado)	10/05/2006	165561	108105	76
Abela Montante	Martinhenos Creek (Sado)	10/05/2006	161849	110563	77
Alfundão	Alfundão Stream (Sado)	16/05/2006	201853	130094.7	78
Barranco das Faias	Faias Creek (Sado)	16/05/2006	197931	136420	84
Canal Caveira	Grândola Stream (Sado)	10/05/2006	173061.8	128135.2	79
Galo Jusante	Alcáçovas Stream (Sado)	15/05/2006	198644.5	163487.9	80
Grândola	Grândola Stream (Sado)	10/05/2006	158182	132584	81
Marateca	Marateca Stream (Sado)	02/06/2006	168783	179130	82
Peramanca	Peramanca Stream (Sado)	15/05/2006	206815.8	165371.5	83
Ponte do Galo	Alcáçovas Stream (Sado)	15/05/2006	201845.7	163611.3	86
Prata	Prata Stream (Sado)	02/06/2006	195966.41	171619.03	85
Ribeira de Alfundão	Alfundão Stream (Sado)	16/05/2006	205961	129218	87
Ribeira de Gema	Gema Stream (Sado)	10/05/2006	173695	97598	88
Ribeira de Grândola	Grândola Stream (Sado)	10/05/2006	162444	133593.5	89
Ribeira de Odivelas	Odivelas Stream (Sado)	16/05/2006	211490	139928	90
Ribeira de São Domingos	São Domingos Stream (Sado)	10/05/2006	160506	108387	91
Ribeira de São Martinho	São Martinho Stream (Sado)	05/04/2006	169645	173282	92
Sado - Corona	Sado River (Sado)	10/05/2006	176549	121321	100
Sado a Jusante da Corona	Sado River (Sado)	10/05/2006	175713	122988	99
São Cristovão Jusante	São Cristovão Stream (Sado)	02/06/2006	187577	170598	93
São Cristovão Montante	São Cristovão Stream (Sado)	02/06/2006	194118	180250	94

Site	Watercourse (Main Basin)	Sampling date	UTM X	UTM Y	ID
São Domingos Jusante	São Domingos Stream (Sado)	10/05/2006	154877	111022	95
Vale de Arca	Vale da Ursa Stream (Sado)	15/05/2006	188201	153105	96
Valverde	São Brissos Stream (Sado)	15/05/2006	203979.3	164938	97
Xarrama	Xarrama River (Sado)	15/05/2006	205732.2	154794.4	98
Agroal	Nabão River (Tejo)	26/06/2006	173754.27	301275.67	101
Aldeia de Freiras	Pêra Stream (Tejo)	09/07/2006	195255	328231	102
Alenquer	Alenquer River (Tejo)	01/07/2006	122322	232946	103
Amieira	Tejo River (Tejo)	06/07/2006	225585	284013	104
Arrouquelas	Lebre Stream (Tejo)	30/06/2006	134348.38	254155.92	105
Aveiras	Aveiras Stream (Tejo)	01/07/2006	137334	236976	106
Azoia	Cabanas Stream (Tejo)	01/07/2006	151210	257848	107
Barbaído	Tripeiro River (Tejo)	11/07/2006	244200.04	329061.23	108
Barco	Zêzere River (Tejo)	08/07/2006	243361.27	355995.07	109
Barquinha	Tejo River (Tejo)	06/07/2006	174112	276397	110
Bazágueda	Bazágueda River (Tejo)	07/07/2006	288640.86	357549.6	111
Belmonte	Zêzere River (Tejo)	06/07/2006	265693	377495	112
Belver	Tejo River (Tejo)	06/07/2006	211141	279044	113
Boeiro	Sertã Stream (Tejo)	09/07/2006	206164	317128	114
Boidobra	Corges Stream (Tejo)	07/07/2006	256689	366749	115
Bouçã	Zêzere River (Tejo)	09/07/2006	191899	320769	116
Cachoeiras	Cardosinhas Stream (Tejo)	01/07/2006	122924.11	223869.48	117
Campinho	Aravil River (Tejo)	12/07/2006	281507.11	313244.3	118
Carregal	Zêzere River (Tejo)	09/07/2006	232646.26	346652.65	119
Carregueira	Carregueira Stream (Tejo)	26/06/2006	209689.44	287069.77	120
Casais do Vidigão	Vidigão Stream (Tejo)	01/07/2006	144741.63	258458.99	121
Casal das Aboboreiras	Lousa Stream (Tejo)	26/06/2006	181190	296516	123
Casal das Antas	Grande da Pipa Stream (Tejo)	01/07/2006	122629.04	224622.93	122
Casal Rei	Zêzere River (Tejo)	26/06/2006	183019	282725	124
Casalinhas	Campo Stream (Tejo)	16/06/2006	276029.71	304174.56	125
Cerejeira	Nabão River (Tejo)	26/06/2006	180710.39	283820.92	126
Chamusca	Tejo River (Tejo)	06/07/2006	169097	265868	127
Chão Forca	Sertã Stream (Tejo)	09/07/2006	202360	314813	128
Constância	Tejo River (Tejo)	06/07/2006	182580	278748	129

Site	Watercourse (Main Basin)	Sampling date	UTM X	UTM Y	ID
Coutada	Zêzere River (Tejo)	08/07/2006	247194.7	357869.01	130
Crato	Seda Stream (Tejo)	29/06/2006	243537	255781	131
Engenho	Alge Stream (Tejo)	09/07/2006	185570	330001	132
Escusa	Sorraia River (Tejo)	03/07/2006	182969	227091	133
Foz do Cobrão	Ocreza River (Tejo)	12/07/2006	231082.13	306315.38	134
Fronteira	Grande Stream (Tejo)	13/04/2006	245436.4	233409.55	135
Janeiro de Baixo	Zêzere River (Tejo)	08/07/2006	227700.44	342220.28	136
Lavacolhos	Ximassas Stream (Tejo)	08/07/2006	244595.63	351649.34	137
Lentiscais	Farropinha Stream (Tejo)	15/06/2006	257559.05	306320.41	138
Lentiscais	Farropinha Stream (Tejo)	13/04/2007	257559.05	306320.41	139
Lezíria	Zêzere River (Tejo)	08/07/2006	237332.23	352485.07	140
Lousa	Alpreade River (Tejo)	11/07/2006	269118.88	328480.07	141
Machoquinho	Nisa Stream (Tejo)	29/06/2006	252007	272518	142
Malhada	Almuro Stream (Tejo)	27/06/2006	258509.83	224085.43	143
Marmeleiro	Tamolha Stream (Tejo)	11/07/2006	203599	310835	144
Mata da Rainha	Taveiró Stream (Tejo)	24/06/2006	270309	347954	145
Milréu	Codes Stream (Tejo)	30/06/2006	197793.64	295076.08	146
Monforte	Freixo Stream (Tejo)	24/05/2006	260153.17	235089.19	147
Monte da Fazenda	Erra Stream (Tejo)	29/06/2006	191781.15	241158.27	148
Monte da Pedra	Caldeireiros Stream (Tejo)	29/06/2006	232169	268524	154
Monte das Águias	Divôr Stream (Tejo)	03/07/2006	200992	212116	153
Monte das Nogueiras	Tera Stream (Tejo)	27/06/2006	238604.61	203871.96	149
Monte dos Arneiros	Arneiros Stream (Tejo)	24/05/2006	248615.93	233456.31	150
Monte dos Irmãos	Sôr Stream (Tejo)	29/06/2006	194570.97	230812.23	151
Monte dos Pardais	Seda Stream (Tejo)	03/07/2006	209638.15	219401.51	152
Montemor	Almansor River (Tejo)	02/06/2006	190766	187113	155
Ota	Ota Stream (Tejo)	01/07/2006	125250.46	238860.65	156
Pampilhosa	Unhais Stream (Tejo)	09/07/2006	215673	342093	157
Pavia	Freixo Stream (Tejo)	03/07/2006	211758.79	212988.79	158
Pego	Tejo River (Tejo)	06/07/2006	202203	278944	159
Peroviseu	Meimoa Stream (Tejo)	08/07/2006	258269.08	358177.36	160
Pomar	Alvito Stream (Tejo)	11/07/2006	233593.3	322367.15	161
Ponte de Sôr	Longomel Stream (Tejo)	29/06/2006	210624	255359	164

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Ponte Nova	Nisa Stream (Tejo)	26/07/2006	241223	289755	163
Ponte Velha	Sever River (Tejo)	29/06/2006	267742.07	269135.43	162
Portela	Foz Stream (Tejo)	30/06/2006	181905.03	276735.71	165
Porto de Vacas	Zêzere River (Tejo)	09/07/2006	229500	346422	166
Porto Tejo	Açafal Stream (Tejo)	26/07/2006	240771	298512	167
Proença-a-Velha	Taliscas Stream (Tejo)	24/06/2006	277111	340586	168
Relvas	Paúl Stream (Tejo)	08/07/2006	239105.91	355087.98	169
Rio Maior	Rio Maior Stream (Tejo)	01/07/2006	128050.81	264447.62	170
Salgueiro	Meimoa Stream (Tejo)	08/07/2006	270876.86	361096.9	171
Serra do Lobo	Vale Santo Stream (Tejo)	25/06/2006	245866.18	328208.29	172
Valada	Seiça Stream (Tejo)	26/06/2006	165758.7	299901.11	173
Vale das Barrocas	Nabão River (Tejo)	26/06/2006	178812.96	284878.42	174
Vale de Ferradas	Vale Ferradas Stream (Tejo)	11/07/2006	241289.85	326414.43	175
Roliça	Real River (Ribeiras do Oeste)	08/05/2006	109669	261705	176
São Pedro de Muel	São Pedro Stream (Ribeiras do Oeste)	10/06/2007	125859.57	311016.2	177
Colmeias	Agudim Stream (Lis)	10/06/2007	150471	314325	178
Monte Redondo	Santo Aleixo Stream (Lis)	10/06/2007	140952	326911	179
Alcabideque	Bruscos Stream (Mondego)	12/06/2007	171057.9	348917.1	180
Alcafache	Dão River (Mondego)	12/05/2007	222269	404140	181
Almagreira	Arunca River (Mondego)	10/06/2007	156444.6	335913.6	182
Alvoco das Várzeas	Alvoco Stream (Mondego)	11/06/2007	226046.5	370292.9	183
Anobra	Arzila Stream (Mondego)	12/06/2007	166723	352607	184
Assamaça	Valmar Stream (Mondego)	10/06/2007	157483	324967.6	205
Cabreira	Ceira River (Mondego)	11/06/2007	205669.2	352507.8	185
Casal da Misarela	Mondego River (Mondego)	12/06/2007	180020	359068	186
Choupal sul	Mondego River (Mondego)	12/06/2007	171844	361223	187
Coiço	Mondego River (Mondego)	13/06/2007	189827	370831	188
Côja 1	Alva River (Mondego)	11/06/2007	212689.3	367278.6	189
Côja 2	Mata Stream (Mondego)	11/06/2007	212718	366085	190
Espinhal	Azenha Stream (Mondego)	10/06/2007	182692	338396	191
Fail	Pavia River (Mondego)	12/05/2007	213359	404273	192
Folgosinho	Freixo Stream (Mondego)	12/05/2007	253868.1	395922.8	193
Foz de Arouce	Ceira River (Mondego)	13/06/2007	187789	354751.3	194

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Foz do Alva	Alva River (Mondego)	13/06/2007	190959	369442	195
Foz do Caneiro	Mondego River (Mondego)	12/06/2007	184001	362976	196
Foz do Ceira	Ceira River (Mondego)	13/06/2007	178543	355556	197
Góis	Ceira River (Mondego)	11/06/2007	201780	353582	198
Granja do Ulmeiro	Mondego River (Mondego)	12/06/2007	158831	357287	199
Laborins	Alva River (Mondego)	13/06/2007	193239.7	369109.8	200
Loriga	Nave Stream (Mondego)	11/06/2007	238694.5	373333.9	201
Lorvão	Lorvão Stream (Mondego)	13/06/2007	185500	365409	202
Piscinas da Lousã	São João Stream (Mondego)	11/06/2007	191413.3	347982.5	203
Pombal-Sul	Arunca River (Mondego)	10/06/2007	156933.1	325352.9	204
Quinta do Mondego (Caldas)	Mondego River (Mondego)	12/05/2007	226294.4	392673.1	206
Redinha	Anços River (Mondego)	10/06/2007	161502	336742.8	207
Sabugueiro	Fervença Stream (Mondego)	07/07/2007	242048.1	381543.6	209
Sameice	Seia River (Mondego)	12/05/2007	230407	386031	210
São João do Monte	Mondego River (Mondego)	12/05/2007	230357	393927.9	208
Tourigo	Marruge Stream (Mondego)	13/05/2007	194182.4	391923.2	211
Vale de Azares	Cabeça Alta Stream (Mondego)	12/05/2007	265995	404087.6	212
Valezim	Valezim Stream (Mondego)	07/07/2007	235137	376667	213
Vidual	Tapado Stream (Mondego)	13/06/2007	186610	354211	214
Açude da Moreira	Caima River (Vouga)	09/07/2007	180728	431062	215
Alfusqueiro	Alfusqueiro River (Vouga)	14/06/2007	180592	406322	216
Carvalhal	Caima River (Vouga)	08/07/2007	172360	418175	217
Cercosa	Alfusqueiro River (Vouga)	08/07/2007	192537.8	412501.3	218
Daires	Pequeno Stream (Vouga)	13/05/2007	190105	401800	219
Estarreja	Antuã River (Vouga)	09/07/2007	163552	420607	220
Fataunços	Ribamá Stream (Vouga)	14/06/2007	205662	417496	221
Fornelo	Vouga River (Vouga)	09/07/2007	189842.3	421233.4	222
Foz	Vouga River (Vouga)	08/07/2007	176698.3	413193.9	223
Guístola	Agadão River (Vouga)	13/05/2007	184537.3	395909.3	224
Manhouce	Manhouce Stream (Vouga)	14/06/2007	193187	428510	225
Mosteirinho	Agadão River (Vouga)	12/05/2007	189767	395755	226
Praia Fluvial de São João do Monte	Águeda River (Vouga)	13/05/2007	191282	403032	227
Ribeira de Fráguas	Azenha da Costa Má (Vouga)	08/07/2007	174222	419545	228

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São João do Monte	Águeda River (Vouga)	08/07/2007	182837.1	401749.5	229
Segadães	Vouga River (Vouga)	13/05/2007	168997.1	404595.1	230
Seixo	Fojo Creek (Vouga)	14/06/2007	148816	389260	231
Vale de Cambra	Caima River (Vouga)	09/07/2007	177584	429467	232
Valmaior	Caima River (Vouga)	08/07/2007	172658	415417	233
Alfândega da Fé	Alambiques Stream (Douro)	21/07/2007	299060.8	487660.7	234
Adobispo	Torto River (Douro)	18/08/2007	265597.03	445006.48	297
Agunchos	Louredo Stream (Douro)	25/09/2007	219104.48	502076.6	262
Agunchos	Tâmega River (Douro)	25/09/2007	219067.99	502164.84	292
Alfaião (Bragança)	Fervença River (Douro)	10/08/2007	318722.3	533531.3	261
Almodena (Vila Real)	Cabril River (Douro)	15/08/2007	231319.8	480969.6	241
Alvre Aguiar de Sousa (Valongo)	Sousa River (Douro)	16/09/2007	175861.6	462662.6	289
Azevo	Côa River (Douro)	18/08/2007	286463.41	431285.45	248
Balsa (Parada do Pinhão)	Pinhão River (Douro)	16/08/2007	245433.4	486225.7	274
Balsamão	Azibo River (Douro)	12/07/2007	307039.18	501280.46	237
Barcos	Tedo River (Douro)	15/09/2007	242069.11	461935.97	293
Barragem de Vila Chã (Agrelos)	Russilhão River (Douro)	16/08/2007	252022.1	482658.7	275
Barrela	Pinhão River (Douro)	15/08/2007	243752.75	493573.75	273
Beira Grande	Cibio Stream (Douro)	26/07/2007	269867.7	466314.2	245
Bemposta (Reservoir) 1	Douro River (Douro)	14/09/2007	338645.5	481964.8	255
Bemposta (Reservoir) 2	Douro River (Douro)	14/09/2007	338021.1	480367.7	256
Bragada	Bragada Stream (Douro)	11/08/2007	305531.44	519054.41	236
Bucos Além Rio	Carvoeiras Stream (Douro)	25/09/2007	208844.18	510726.63	240
Carvalhosa	Carvalhosa Stream (Douro)	16/09/2007	179124.5	478591	244
Chã	Monim Stream (Douro)	16/08/2007	249745.35	485004.41	266
Cinco Vilas	Côa River (Douro)	18/08/2007	296636.68	424514.4	246
Cobro (Mirandela)	Orelhão River (Douro)	21/07/2007	274014.6	494439.8	300
Curaceda	Trovisco River (Douro)	19/08/2007	303403.6	464846	299
Curros	Curros River (Douro)	14/08/2007	256391.8	504451	254
Eixos (Mirandela)	Rabaçal River (Douro)	14/08/2007	276991.9	505780.2	278
Eixos (Mirandela) 2	Rabaçal River (Douro)	14/08/2007	275249.7	506389.3	277
Ermida	Ermida Stream (Douro)	15/09/2007	214362.98	439103.69	308
Estevais	Estevais Stream (Douro)	19/08/2007	310563.6	471496.1	260

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Felgar	Sabor River (Douro)	19/08/2007	297625.49	475150.44	284
Flores (Vila Real)	Corgo River (Douro)	15/08/2007	234333.6	483134.5	252
Folgosa	Paiva River (Douro)	15/09/2007	219620.29	435803.81	272
Foz do Azibo	Sabor River (Douro)	12/08/2007	310990.64	494039.15	238
Freixiel	Redonda Stream (Douro)	21/07/2007	276369.6	483642.8	279
Freixiel	Uceira Stream (Douro)	11/08/2007	274131.5	467351.4	305
Fridão/Canadelo	Olo River (Douro)	15/08/2007	212195.36	483455.32	268
Guribanes	Tuela River (Douro)	14/08/2007	280538.39	511831.26	303
Horta da Vilariça (Vila Flor)	Grande Stream (Douro)	16/08/2007	285656.2	475143	309
Izeda/Morais	Vale de Moinhos Stream (Douro)	11/08/2007	316039.7	507704.1	307
Junqueira	Maçãs River (Douro)	12/08/2007	323747.65	500209.64	263
Lamas de Olo	Olo River (Douro)	15/08/2007	228469.26	88726.83	269
Mazes (Lamego)	Poldras River (Douro)	15/09/2007	223749	450152.5	276
Meirinhos	Freixo Stream (Douro)	21/07/2007	310747	479118.8	265
Meirinhos	Sabor River (Douro)	19/08/2007	305361.45	480028.91	286
Miranda do Douro (Reservoir)	Douro River (Douro)	12/08/2007	354915.3	503035.8	257
Mouth of Azibo River	Sabor River (Douro)	12/08/2007	312291.8	494084.9	283
Malhadais	Mosteiró River (Douro)	19/08/2007	303121.97	454944.33	267
Near Quinta de São Tiago	Santa Marinha Sream (Douro)	25/07/2007	302058.9	463011.9	288
Nozelos	Macedo Stream (Douro)	11/08/2007	287967.5	519882.2	264
Parada de Ester	Ester Stream (Douro)	15/09/2007	208705.72	440347.72	259
Parâmio	Baceiro River (Douro)	10/08/2007	306219.6	547929.02	239
Pinhal do Douro	Coleja Stream (Douro)	26/07/2007	274816	466514.4	251
Ponte da Pedra	Tuela River (Douro)	11/07/2007	282522	522963.6	304
Ponte de Santulhão	Sabor River (Douro)	11/08/2007	321710.3	510895.2	282
Porto de Ovelha	Côa River (Douro)	17/08/2007	300154.94	395992.86	249
Povoação	Torno River (Douro)	15/08/2007	236281.25	501261.23	295
Quinta das Quebradas	Caravelas Stream (Douro)	22/07/2007	315514.8	474752.9	243
Rabal	Sabor River (Douro)	10/08/2007	316149.1	547444.1	287
Ranhados (Penedono)	Torto River (Douro)	18/08/2007	266962	449301	298
Ribeira de Fraga – Carrazedo de Montenegro	Curros River (Douro)	14/08/2007	258391.9	507999.1	253
Ribeira de Pena	Tâmega River (Douro)	24/09/2007	228877.1	508149.4	290
Roios (Quinta do Vale da Cal)	Roios Stream (Douro)	21/07/2007	285255	483096.5	281

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Rossas (Arouca)	Urtigosa River (Douro)	15/09/2007	184797.7	438185.1	271
Sabor 3 (Ponte do Sabor)	Sabor River (Douro)	16/08/2007	288054.77	472032.27	285
Sanceriz	Sanceriz Stream (Douro)	11/08/2007	314808.57	514597.53	280
Sandim (Santa Maria da Feira)	Uima River (Douro)	26/07/2007	168769.1	449483.3	306
Santa Valha	Calvo River (Douro)	11/08/2007	270367.35	523231.61	242
Saucelle (near Barca d'Alva)	Douro River (Douro)	14/09/2007	311318.2	452855.8	258
Tejão	Olo River (Douro)	15/08/2007	216797.96	488491.15	270
Torto	Torto River (Douro)	15/09/2007	252455.1	466153.1	296
Tropeço (Arouca)	Arda River (Douro)	15/09/2007	182399.4	440667.6	235
Vale do Armeiro	Rabaçal River (Douro)	10/08/2007	280572.81	533967.99	301
Valongo do Côa/Seixo do Côa	Côa River (Douro)	17/08/2007	294608.76	388879.32	247
Veral	Tâmega River (Douro)	31/07/2007	232550.53	510607.44	291
Vesúvio	Teja River (Douro)	18/08/2007	272298.96	461790.27	294
Vilar Torpim	Lagar de Água Stream (Douro)	24/07/2007	298228.7	429317	250
Vilarinho das Azenhas (Cachão)	Tua River (Douro)	16/08/2007	277859.4	491444.3	302
Além da Veiga	Ave River (Ave)	25/09/2007	189024.75	507642.7	310
Assento	Vizela River (Ave)	22/09/2007	192555.8	492505.46	311
Bicho	Ave River (Ave)	16/09/2007	158888.29	485337.06	312
Brunhais	Ave River (Ave)	25/09/2007	197189.02	512278.5	313
Guilhofrei	Ave River (Ave)	25/09/2007	201685.57	512595.92	314
Guimarães	Selho River (Ave)	22/09/2007	183347.49	496411.44	315
Joane	Pele River (Ave)	30/07/2007	177255.22	497171.56	316
Ponte do Pingue	Moreira Stream (Ave)	25/09/2007	200258.27	499140.89	317
Pontilhões	Ave River (Ave)	22/09/2007	181914.65	498145.67	318
Real	Docim Stream (Ave)	25/09/2007	200467.22	497968.54	319
Retorta	Ave River (Ave)	16/09/2007	150238.68	488035.6	320
Vilela	Pequeno River (Ave)	25/09/2007	189743.09	508876.07	321
Abelheira	Abelheira Stream (Cávado)	24/09/2007	211337.79	534213.73	322
Alto Cávado	Cávado River (Cávado)	24/09/2007	222474.77	538297.68	323
Arcozelo	Pontes Stream (Cávado)	22/09/2007	160957.81	510051.29	324
Areias de Vilar	Cávado River (Cávado)	22/09/2007	164846.58	508466.62	325
Barcelos	Cávado River (Cávado)	22/09/2007	159607.52	506883.93	326
Barral	Homem River (Cávado)	26/09/2007	179091.37	522618.94	327

Site	Watercourse (Main Basin)	Sampling date	UTM X	UTM Y	ID
Cavacadouro	Homem River (Cávado)	26/09/2007	185810.22	527909.24	328
Marachão	Cávado River (Cávado)	22/09/2007	151078.6	504070.04	329
Montalegre	Cávado River (Cávado)	24/09/2007	226632.08	540138.54	330
Moure	Águas Santas Stream (Cávado)	27/09/2007	183513.79	515332.35	331
Parada do Bouro	Cávado River (Cávado)	26/09/2007	190283.97	520065.15	332
Pico de Regalados	Tojal Stream (Cávado)	26/09/2007	176475.25	524157.76	333
Ponte na EN 103	Rabagão River (Cávado)	24/09/2007	221580.78	528723.8	334
Portela do Homem	Homem River (Cávado)	26/09/2007	200326.08	536996.95	335
Sequeirós	Homem River (Cávado)	26/09/2007	188479.26	530117.03	336
Vila da Ponte	Rabagão River (Cávado)	24/09/2007	219034.12	527716.93	337
Vilar da Veiga	Gerês River (Cávado)	26/09/2007	196850.05	526415.33	338
Cantim	Leça River (Leça)	16/09/2007	171754.08	478155.16	339
Vermoim	Arquinho Stream (Leça)	16/09/2007	160857.71	475571.18	340
Arcos de Valdevez	Vez River (Lima)	21/09/2007	176395	540476.53	341
Cidadelhe	Lima River (Lima)	27/09/2007	189445.04	543542.63	342
Férrea	Peneda River (Lima)	20/09/2007	192196.82	554846.49	343
Froufe	Froufe River (Lima)	27/09/2007	187325.86	539248.14	344
Lanheses	Lima River (Lima)	21/09/2007	155169.07	529023.19	345
Monte Branco	Neiva River (Lima)	22/09/2007	148999.41	516694.42	346
Outeiro das Cabras	Âncora River (Lima)	21/09/2007	150137.19	536549.72	347
Ribeira de Reis Magos	Reis Magos Stream (Lima)	08/08/2007	151782.82	519039.08	348
Ribeiro de Baixo	Castro Laboreiro River (Lima)	20/09/2007	195756.52	553401.03	349
Senra	Lima River (Lima)	27/09/2007	179656.99	538525.78	350
Sub-Igreja	Vez River (Lima)	21/09/2007	174200.86	550048.53	351
Tregosa	Neiva River (Lima)	22/09/2007	153592.8	519388.15	352
Arão	Minho River (Minho)	20/09/2007	156702.47	561439.5	353
Covas	Coura River (Minho)	21/09/2007	152977.43	545445.96	354
Gadanha	Gadanha River (Minho)	20/09/2007	169527.69	562554.53	355
Lamas de Mouro	Mouro River (Minho)	20/09/2007	194199.41	563701.09	356
Monção	Minho River (Minho)	20/09/2007	170101.06	568130.77	357
Ribeiro do Porto	Porto Stream (Minho)	20/09/2007	188818.14	572099.95	358
Rubiães	Coura River (Minho)	21/09/2007	158510.81	547622.79	359
Segude	Mouro River (Minho)	20/09/2007	178819.46	564229.86	360

Site	Watercourse (Main Basin)	Sampling date	UTM X	UTM Y	ID
Soutelo	Coura River (Minho)	21/09/2007	166675.45	549873.53	361
Troporiz	Gadanha River (Minho)	20/09/2007	167503.62	565609.09	362
Truticultura	Coura River (Minho)	21/09/2007	162638.81	550069.45	363
Veiga de Remoães	Minho River (Minho)	20/09/2007	187184.31	571637.19	364

During the time of this study there was the opportunity to study seasonally eighteen **reservoirs** distributed throughout the whole Portuguese territory, in the framework of the national project "Qualidade ecológica e gestão integrada de albufeiras" Contrato protocolar nº 2003/067/INAG. Since the diatom flora of lentic systems is somehow different from the one present in lotic systems with more planktonic species, these results were integrated in the present work in order to complement the information on the Portuguese freshwater diatom flora.

Epilithic littoral diatoms were seasonally collected from stones in the margins of eighteen reservoirs following the European recommendations for sampling in lakes (KING et al. 2006), by the sampling team of the project, between February and November 2006.

Water samples for chemical analyses were collected approximately one month previous to the diatom sampling and also simultaneously with diatom samples. Water samples were kept cold and in the dark until laboratory processing. Environmental parameters such as temperature (℃), pH, concentration of dissolved oxygen (mg L^{-1}) and specific conductivity (µS cm^{-1}) were measured *in situ* with portable instruments calibrated in the field.

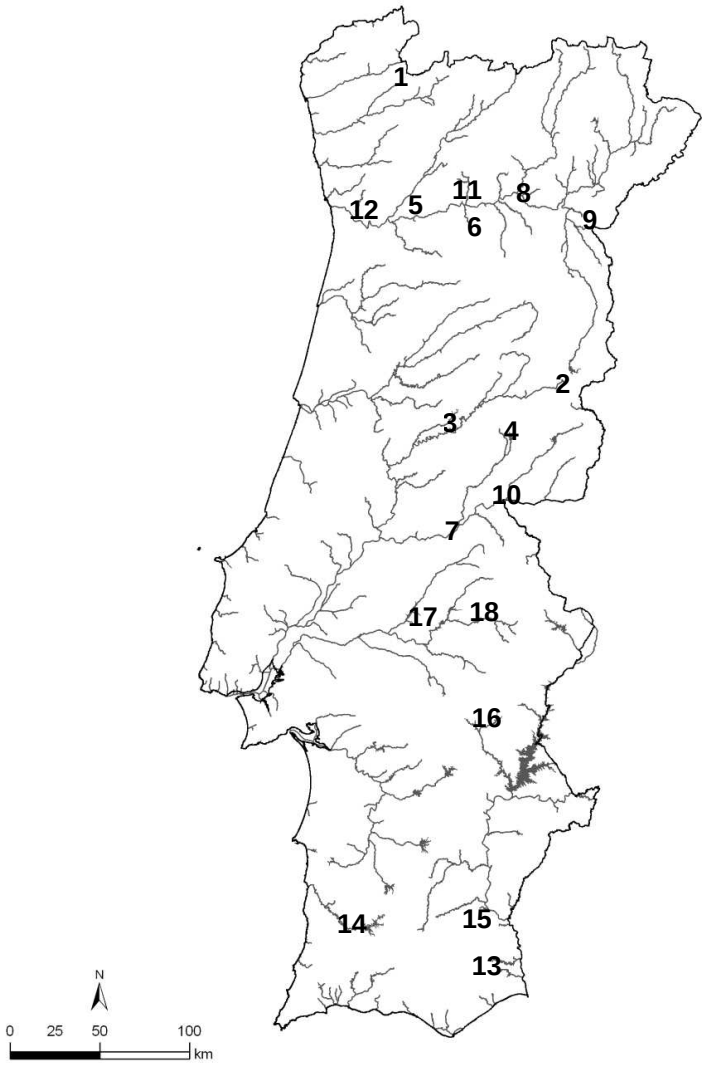

Figure 3.3 Map with the location of the studied reservoirs in Portugal.

Table 3.2 Morphometric characterization and INAG pre-classification of hydromorphological types of the studied reservoirs.

Reservoir name	Hydrographic basin	Year of construction	Volume (hm^3)	Depth (m)	Hydromorphological type
1 - Vilarinho das Furnas	Cávado	1972	118	94	North
2 - Meimoa	Tejo	1985	41	50	North
3 - Santa Luzia	Tejo	1942	54	76	North
4 - Marateca	Tejo	1991	37	25	North
5 - Torrão	Douro	1988	124	69	North
6 - Varosa	Douro	1976	13	76	North
7 - Belver	Tejo	1952	13	30	Main Courses
8 - Valeira	Douro	1976	97	48	Main Courses
9 - Pocinho	Douro	1982	81	49	Main Courses
10 - Fratel	Tejo	1973	93	43	Main Courses
11 - Régua	Douro	1973	95	41	Main Courses
12 - Crestuma	Douro	1985	106	65	Main Courses
13 - Odeleite	Guadiana	1997	132	50	South
14 - Santa Clara	Mira	1968	485	83	South
15 - Tapada Grande	Guadiana	1984	10	18	South
16 - Monte Novo	Guadiana	1982	15	30	South
17 - Montargil	Tejo	1958	180	36	South
18 - Maranhão	Tejo	1957	220	49	South

3.2.2 Laboratory techniques

Standard methods for water chemical analysis were carried out according to APHA (1995) and comprise the following water variables: alkalinity (mg HCO_3^- L^{-1}), ammonia (mg NH_4 L^{-1}), biological oxygen demand after 5 days (BOD_5, mg O_2 L^{-1}), calcium (mg Ca^{2+} L^{-1}), chemical oxygen demand (COD), chlorine (mg Cl^- L^{-1}), nitrates (mg NO_3^- L^{-1}), nitrites (mg NO_2^- L^{-1}), potassium (K^+), phosphate (mg P_2O_5 L^{-1}), silica (mg SiO_2 L^{-1}), sodium (mg Na^+ L^{-1}), soluble reactive phosphorus (SRP) (mg P L^{-1}), sulphate (mg SO_4^{2-} L^{-1}), total hardness (mg $CaCO_3$ L^{-1}), total organic carbon TOC (mg O_2 L^{-1}) and total phosphorus (mg P L^{-1}). All the chemical analyses were performed in the Water Laboratory of the University of Évora (Portugal).

Diatom treatment and analysis of both watercourses and reservoirs samples followed the Portuguese protocol (INAG 2008) and European norms (AFNOR 2000; European Committee for Standardization 2004) and consisted in the oxidation of the samples using hot hydrogen peroxide (35%) and diluted HCl (37 %) in order to obtain a suspension of clean frustules. Permanent slides were mounted with Naphrax®. Light microscopy (LM) observations were performed using a Leica® DMRX brightfield microscope with 100 x oil immersion objective and LM photographs were taken with a Leica® DC500 camera.

Samples selected for scanning electron microscopy analysis were filtrated through polycarbonate membrane filters with a pore diameter of 3 µm, mounted on stubs using double sided carbon tape. The first part of the samples were sputtered with gold (40 nm) with Modular High Vacuum Coating System (BAL-TEC MED 020), in order to be analysed with a Leica® Stereoscan 430i, operated at 20 kV, and the rest of the samples were sputtered with platinum (30 nm) with Modular High Vacuum Coating System (BAL-TEC MED 020) and studied with a Hitachi SU-70, operated at 5.0 kV.

At least 400 valves were identified and counted from each slide to estimate the relative abundance of each taxon (INAG 2008). The identification was based in reference floras (e.g. KRAMMER & LANGE-BERTALOT 1986, 1988, 1991a,b) as well as in recent bibliography.

For all taxa with relative abundance above 5% in at least one inventory a series of light micrographs to illustrate the whole range of size variability is presented. Furthermore, some taxa with relative abundance below 5% are also illustrated, due to their originality and interest. Whenever possible, taxa which cause identification difficulties are illustrated in SEM. The light micrographs present a magnification of 1500x, in the few exceptions it is indicated in the figure. Every population illustrated is identified by the sampling site, watercourse, basin and sampling date.

For each taxon the following information is provided: taxon name [OMNIDIA code], basionym, nomenclatural synonyms (whenever they are of current use), morphometric measurements from the populations presented, ecological preferences as reconstructed from field observations and the Specific Pollution sensitivity Index (SPI) values of pollution sensitivity (S) and stenoecy degree (V) from OMNIDIA v. 5.3.

For the diatom names, the information provided in the Catalogue of Diatom Names by the California Academy of Sciences (http://research.calacademy.org/research/diatoms/names/) and by the OMNIDIA v. 5.3 software database (LECOINTE et al. 1999) was followed.

Morphometric measurements were made directly from the digital images, since this method is more precise than measurements taken directly by using the ocular scale, as referred also by POTAPOVA & PONADER (2004). Striae density was measured either directly in LM images above or below the centre of the valve in a 10 μm interval or in the scanning electron micrographs in intervals of 2 μm in the centre of the valve (and in the valve apices) and multiplied by 5 in order to obtain the number of striae in 10 μm, depending on the species dimensions. The number of valves (n) measured depends on the species dimensions and abundance in the sample and is indicated in the characterization of each species.

The individual values of pollution sensitivity – S and stenoecy degree - V of the Specific Pollution sensitivity Index (SPI) were assigned to each taxon and are based in the database of the OMNIDIA v. 5.3 software (LECOINTE et al. 1999). The SPI values of individual sensitivity were selected since it is the only diatom index based on the autecological parameters of virtually all known taxa at specific or subspecific levels. It has already been used with good results in Portugal (ALMEIDA 2001) and has been recommended as reference index for several Iberian basins (GOMÀ et al. 2004, 2005; BLANCO et al. 2007, 2008).

Ecological preferences of the taxa that constitute new records for the Iberian Peninsula were inferred based on environmental variables from the sites from Mainland Portugal where they have been found with a relative abundance above 1%. In total 19 environmental parameters were assessed by calculating the abundance weighted-average (WA): current velocity (m s^{-1}), conductivity (μS cm^{-1}), pH, dissolved oxygen (% sat.), dissolved oxygen (mg L^{-1}), alkalinity (mg HCO_3^- L^{-1}), ammonia (mg N L^{-1}), biological oxygen demand after 5 days (BOD_5, mg O_2 L^{-1}), chlorides (mg Cl^- L^{-1}), nitrates (mg N L^{-1}), N-nitrites (mg N L^{-1}), phosphates (mg P L^{-1}), soluble reactive phosphorus (SRP) (mg P L^{-1}), total organic carbon (TOC, mg O_2 L^{-1}), total hardness (mg $CaCO_3$ L^{-1}), total phosphorus (mg P L^{-1}), calcium (mg Ca^{2+} L^{-1}), sodium (mg Na^+ L^{-1}) and sulphates (mg SO_4^{2-} L^{-1}).

The maps with the location of the sampling sites have been generated using the GIS software ArcGIS 9.3 (ESRI 2008).

3.2.3 Classification system

The classification system adopted for the higher ranks (division, subdivision and class) is the one proposed by MEDLIN & KACZMARSKA (2004) and generally confirmed by MANN in ADL et al. (2005). The lower ranks (order, family and genus) follow the classification of ROUND et al. (1990) and the genera described after this work are placed in the different families following the suggestions presented by MONNIER et al. (2009).

Division **Bacillariophyta** HAECKEL 1878

Subdivision **Coscinodiscophytina** MEDLIN & KACZMARSKA 2004

Class **Coscinodiscophyceae** ROUND & R.M. CRAWFORD, emend. MEDLIN & KACZMARSKA 2004

Order **Coscinodiscales** ROUND & R.M. CRAWFORD in ROUND et al. 1990

Family **Hemidiscaceae** HENDEY 1937

Genus ***Actinocyclus*** EHRENBERG 1837

Order **Melosirales** R.M. CRAWFORD in ROUND et al. 1990

Family **Melosiraceae** KÜTZING 1844

Genus ***Melosira*** C. AGARDH 1824

Order **Aulacoseirales** R.M. CRAWFORD in ROUND et al.1990

Family **Aulacoseiraceae** R.M. CRAWFORD in ROUND et al.1990

Genus ***Aulacoseira*** THWAITES 1848

Subdivision **Bacillariophytina** MEDLIN & KACZMARSKA 2004

Class **Mediophyceae** (JOUSÉ & PROSHKINA-LAVRENKO) MEDLIN & KACZMARSKA 2004

Order **Thalassiosirales** GLEZER & I.V. MAKAROVA 1986

Family **Stephanodiscaceae** GLEZER & I.V. MAKAROVA 1986

Genus ***Cyclostephanos*** ROUND ex THERIOT, HÅKANSSON, KOCIOLEK, ROUND & STOERMER 1987

Genus ***Cyclotella*** (KÜTZING) BRÉBISSON 1838

Genus ***Discostella*** HOUK & KLEE 2004

Genus ***Stephanodiscus*** EHRENBERG 1845

Order **Triceratiales** ROUND & R.M. CRAWFORD in ROUND et al.1990

Family **Triceratiaceae** (SCHÜTT) LEMMERMANN 1899

Genus ***Pleurosira*** (MENEGHINI) V.B.A. TREVISAN DI SAN LEON 1848

Class **Bacillariophyceae** HAECKEL, emend. MEDLIN & KACZMARSKA 2004

Order **Fragilariales** P.C. SILVA 1962

Family **Fragilariaceae** GREVILLE 1833

Genus ***Asterionella*** HASSALL 1850

Genus ***Diatoma*** BORY 1824

Genus ***Fragilaria*** LYNGBYE 1819

Genus ***Fragilariforma*** D.M. WILLIAMS & ROUND 1988

Genus ***Pseudostaurosira*** D.M. WILLIAMS & ROUND 1988

Genus ***Punctastriata*** D.M. WILLIAMS & ROUND 1988

Genus ***Staurosira*** EHRENBERG 1843

Genus ***Tabularia*** (KÜTZING) D.M. WILLIAMS & ROUND 1986

Genus ***Ulnaria*** (KÜTZING) COMPÈRE 2001

Order **Tabellariales** ROUND in ROUND et al. 1990

Family **Tabellariaceae** KÜTZING 1844

Genus ***Tabellaria*** EHRENBERG ex KÜTZING 1844

Family **Peroniaceae** (KARSTEN) TOPACHEVSKYJ & OKSIYUK 1960

Genus ***Peronia*** BREBISSON & ARNOTT ex KITTON 1868

Order **Eunotiales** P.C. SILVA 1962

Family **Eunotiaceae** KÜTZING 1844

Genus ***Eunotia*** EHRENBERG 1837

Order **Mastogloiales** D.G. MANN in ROUND et al. 1990

Family **Mastogloiaceae** MERESCHKOWSKY 1903

Genus ***Aneumastus*** D.G. MANN & A.J. STICKLE in ROUND et al. 1990

Order **Cymbellales** D.G. MANN in ROUND et al. 1990

Family **Rhoiscospheniaceae** CHEN & ZHU 1983

Genus ***Rhoicosphenia*** GRUNOW 1860

Family **Cymbellaceae** GREVILLE 1833

Genus ***Cymbella*** C. AGARDH 1830

Genus ***Cymbopleura*** (KRAMMER) KRAMMER 1999

Genus ***Encyonema*** KÜTZING 1833

Genus ***Encyonopsis*** KRAMMER 1997

Genus ***Placoneis*** MERESCHKOWSKY 1903

Family **Gomphonemataceae** KÜTZING 1844

Genus ***Gomphoneis*** CLEVE 1894

Genus ***Gomphonema*** EHRENBERG 1832

Genus ***Gomphosphenia*** LANGE-BERTALOT 1995

Genus ***Reimeria*** KOCIOLEK & STOERMER 1987

Order **Achnanthales** P.C. SILVA 1962

Family **Cocconeidaceae** KÜTZING 1844

Genus ***Cocconeis*** EHRENBERG 1837

Family **Achnanthidiaceae** D.G. MANN in ROUND et al. 1990

Genus ***Achnanthidium*** KÜTZING 1844

Genus ***Karayevia*** ROUND & BUKHTIYAROVA ex ROUND 1998

Genus ***Lemnicola*** ROUND & BASSON 1997

Genus ***Planothidium*** ROUND & BUKHTIYAROVA 1996

Genus ***Psammothidium*** BUKHTIYAROVA & ROUND 1996

Order **Naviculales** BESSEY 1907

Suborder **Neidiineae** D.G. MANN in ROUND et al. 1990

Family **Diadesmidaceae** D.G. MANN in ROUND et al. 1990

Genus ***Diadesmis*** KÜTZING 1844

Genus ***Luticola*** D.G. MANN in ROUND et al. 1990

Genus ***Nupela*** VYVERMAN & COMPÈRE 1991

Family **Amphipleuraceae** GRUNOW 1862

Genus ***Amphipleura*** KÜTZING 1844

Family **Brachysiraceae** D.G. MANN in ROUND et al. 1990

Genus ***Brachysira*** KÜTZING 1836

Family **Neidiaceae** MERESCHKOWSKY 1903

Genus ***Neidium*** PFITZER 1871

Suborder **Sellaphorineae** D.G. MANN in ROUND et al. 1990

Family **Sellaphoraceae** MERESCHKOWSKY 1902

Genus ***Adlafia*** GERD MOSER, LANGE-BERTALOT & METZELTIN 1998

Genus ***Chamaepinnularia*** LANGE-BERTALOT & KRAMMER 1996

Genus ***Eolimna*** LANGE-BERTALOT & SCHILLER 1997

Genus ***Fallacia*** A.J. STICKLE & D.G. MANN in ROUND et al. 1990

Genus ***Fistulifera*** LANGE-BERTALOT 1997

Genus ***Mayamaea*** LANGE-BERTALOT 1997

Genus ***Sellaphora*** MERESCHKOWSKY 1902

Family **Pinnulariaceae** D.G. MANN in ROUND et al. 1990

Genus ***Caloneis*** CLEVE 1894

Genus ***Pinnularia*** EHRENBERG 1843

Suborder **Diploneidineae** D.G. MANN in ROUND et al. 1990

Family **Diploneidaceae** D.G. MANN in ROUND et al. 1990

Genus ***Diploneis*** (EHRENBERG) CLEVE 1894

Suborder **Naviculineae** HENDEY 1937

Family **Naviculaceae** KÜTZING 1844

Genus ***Geissleria*** LANGE-BERTALOT & METZELTIN 1996

Genus ***Hippodonta*** LANGE-BERTALOT, WITKOWSKI & METZELTIN 1996

Genus ***Navicula*** BORY 1822

Family **Stauroneidaceae** D.G. MANN in ROUND et al. 1990

Genus ***Craticula*** GRUNOW 1867

Genus ***Stauroneis*** EHRENBERG 1927

Order **Thalassiophysales** D.G. MANN in ROUND et al. 1990

Family **Catenulaceae** MERESCHKOWSKY 1903

Genus ***Amphora*** EHRENBERG ex KÜTZING 1844

Genus ***Halamphora*** (CLEVE) LEVKOV 2009

Order **Bacillariales** HENDEY 1937

Family **Bacillariaceae** EHRENBERG 1831

Genus ***Nitzschia*** HASSALL 1845

Genus ***Tryblionella*** W. SMITH 1853

Order **Rhopaloidales** D.G. MANN in ROUND et al. 1990

Family **Rhopalodiaceae** (Karsten) TOPACHEVS'KYJ & OKSIYUK 1960

Genus ***Epithemia*** Kützing 1844

Genus ***Rhopalodia*** O. MÜLLER 1895

Order **Surirellales** D.G. MANN in ROUND et al. 1990

Family **Surirellaceae** KÜTZING 1844

Genus ***Cymatopleura*** W. SMITH 1851

Genus ***Surirella*** TURPIN 1828

3.3 Results and Discussion

3.3.1 Species diversity

A total of 570 diatom taxa have been inventoried in the watercourses studied, from which 286 were present with abundance above 1% in at least one sample (Table 3.3). These 286 taxa belong to 61 genera, being *Achnanthidium* (29 taxa), *Nitzschia* (29 taxa), *Gomphonema* (26 taxa), *Navicula* (24 taxa), *Fragilaria* (20 taxa) and *Eunotia* (12 taxa) the most represented. Nevertheless, there were several taxa (26) which posed identification difficulties and are represented by cf. and aff. notations and 26 taxa could not be identified to species level. A total of 39 taxa were new records for the country and 11 were new records for the Iberian Peninsula (Table 3.3).

Table 3.3 List of the taxa presented with abundance above 1% in at least one inventory from the studied watercourses. One asterisk identifies new records for Portugal and two asterisks identify new records for Iberian Peninsula.

Code	Taxon
**AHMI	*Achnanthes helvetica* var. *minor* Flower & Jones 1989
*ADAM	*Achnanthidium atomoides* Monnier, Lange-Bertalot & Ector
ADCT	*Achnanthidium catenatum* (Bílý & Marvan) Lange-Bertalot
	Achnanthidium cf. *subatomus* (Hustedt) Lange-Bertalot
*ADDA	*Achnanthidium daonense* (Lange-Bertalot) Lange-Bertalot, Monnier & Ector
*ADEU	*Achnanthidium eutrophilum* (Lange-Bertalot) Lange-Bertalot
ADEG	*Achnanthidium exiguum* (Grunow) Czarnecki sensu lato
ADGL	*Achnanthidium gracillimum* (F. Meister) Lange-Bertalot
ACLI	*Achnanthidium lineare* W. Smith
	Achnanthidium aff. *lineare* W. Smith
	Achnanthidium lineare W. Smith abnormal form
ADMA	*Achnanthidium macrocephalum* (Hustedt) Round & Bukhtiyarova
ADMI	*Achnanthidium minutissimum* (Kützing) Czarnecki
ADMT	*Achnanthidium minutissimum* (Kützing) Czarnecki abnormal form
ADMI	*Achnanthidium minutissimum* (Kützing) Czarnecki s.l.
ADPY	*Achnanthidium pyrenaicum* (Hustedt) Kobayasi
*ADRI	*Achnanthidium rivulare* Potapova & Ponader
ADRT	*Achnanthidium rivulare* Potapova & Ponader abnormal form
ADSA	*Achnanthidium saprophilum* (Kobayasi & Mayama) Round & Bukhtiyarova
	Achnanthidium aff. *saprophilum* (Kobayasi & Mayama) Round & Bukhtiyarova
	Achnanthidium pseudolineare Van de Vijver, Novais & Ector
	Achnanthidium caravelense Novais & Ector
	Achnanthidium sp.3

	Achnanthidium sp.4
	Achnanthidium sp.5
	Achnanthidium sp.6
	Achnanthidium sp.7
	Achnanthidium sp.8
	Achnanthidium sp.9
*ADSB	*Achnanthidium straubianum* (Lange-Bertalot) Lange-Bertalot
ADSO	*Achnanthidium subatomoides* (Hustedt) Monnier, Lange-Bertalot & Ector
ADSH	*Achnanthidium subhudsonis* (Hustedt) H. Kobayasi
ANMN	*Actinocyclus normanii* (Gregory ex Greville) Hustedt
ADMS	*Adlafia minuscula* (Grunow) Lange-Bertalot
	Adlafia sp.1
	Adlafia sp.2
ACOP	*Amphora copulata* (Kützing) Schoeman & Archibald
*AMID	*Amphora indistincta* Levkov
*ALGT	*Amphora lange-bertalotii* var. *tenuis* Levkov & Metzeltin
AOVA	*Amphora ovalis* (Kützing) Kützing
APED	*Amphora pediculus* (Kützing) Grunow
AAMB	*Aulacoseira ambigua* (Grunow) Simonsen
**	*Aulacoseira ambigua* f. *japonica* (F. Meister) Tuji & D.M. Williams
AUDI	*Aulacoseira distans* (Ehrenberg) Simonsen
AUGR	*Aulacoseira granulata* (Ehrenberg) Simonsen
AUGA	*Aulacoseira granulata* (Ehrenberg) Simonsen var. *angustissima* (O. Müller) Simonsen
**AUPU	*Aulacoseira pusilla* (F. Meister) Tuji & Houki
	Aulacoseira cf. *subarctica* (O. Müller) Haworth
*AUTL	*Aulacoseira tenella* (Nygaard) Simonsen
AULS	*Aulacoseira* sp.
BBRE	*Brachysira brebissonii* Ross in Hartley
BNEG	*Brachysira neglectissima* Lange-Bertalot
	Caloneis aff. *lancettula* (Schulz) Lange-Bertalot & Witkowski
	Chamaepinnularia cf. *rexii* Veselá & Johansen
CEUG	*Cocconeis euglypta* Ehrenberg
CLNT	*Cocconeis lineata* Ehrenberg
	Cocconeis lineata Ehrenberg abnormal form
*CNTH	*Cocconeis neothumensis* Krammer
CPED	*Cocconeis pediculus* Ehrenberg
CPPL	*Cocconeis placentula* var. *pseudolineata* Geitler
CPEO	*Cocconeis placentula* var. *euglyptoides* Geitler
COCS	*Cocconeis* sp.
CRCU	*Craticula cuspidata* (Kützing) D.G. Mann
CTPU	*Ctenophora pulchella* (Ralfs ex Kützing) D.M. Williams & Round
CDUB	*Cyclostephanos dubius* (Fricke) Round
CINV	*Cyclostephanos invisitatus* (Hohn & Hellerman) Theriot, Stoermer & Håkansson
CATO	*Cyclotella atomus* Hustedt
CMEN	*Cyclotella meneghiniana* Kützing
COCE	*Cyclotella ocellata* Pantocsek
CAFF	*Cymbella affinis* Kützing
CAEX	*Cymbella excisa* Kützing

**CPPV	*Cymbella perparva* Krammer
	Cymbella cf. *tropica* Krammer
CTUM	*Cymbella tumida* (Brébisson) Van Heurck
CTGL	*Cymbella turgidula* Grunow
CBNA	*Cymbopleura naviculiformis* (Auerswald) Krammer
DSUB	*Denticula subtilis* Grunow
	Diadesmis cf. *biceps* Arnott ex Grunow
DCOF	*Diadesmis confervacea* Kützing
DCOT	*Diadesmis contenta* (Grunow ex Van Heurck) D.G. Mann
DPER	*Diadesmis perpusilla* (Grunow) D.G. Mann sensu lato
DHIE	*Diatoma hyemalis* (Roth) Heiberg
DMES	*Diatoma mesodon* (Ehrenberg) Kützing
DELL	*Diploneis elliptica* (Kützing) Cleve
*DSEP	*Diploneis separanda* Lange-Bertalot
DPST	*Discostella pseudostelligera* (Hustedt) Houk & Klee
DSTE	*Discostella stelligera* (Cleve & Grunow) Houk & Klee
*ENLB	*Encyonema lange-bertalotii* Krammer
	Encyonema cf. *minutiforme* Krammer 1997
ENMI	*Encyonema minutum* (Hilse in Rabenhorst) D.G. Mann
ENNG	*Encyonema neogracile* Krammer
EPRO	*Encyonema prostratum* (Berkeley) Kützing
ELSE	*Encyonema silesiacum* (Bleisch in Rabenhorst) D.G. Mann
	Encyonema cf. *silesiacum* (Bleisch in Rabenhorst) D.G. Mann
ENSP	*Encyonema* sp.
ENVE	*Encyonema ventricosum* (C. Agardh) Grunow
EAQL	*Encyonopsis aequalis* (W. Smith) Krammer
*EOCO	*Eolimna comperei* Ector, Coste & Iserentant
EOMI	*Eolimna minima* (Grunow) Lange-Bertalot
EOMT	*Eolimna minima* (Grunow) Lange-Bertalot abnormal form
ESBM	*Eolimna subminuscula* (Manguin) Moser, Lange-Bertalot & Metzeltin
EOSP	*Eolimna* sp.
EADN	*Epithemia adnata* (Kützing) Brébisson
ESOR	*Epithemia sorex* Kützing
EEXI	*Eunotia exigua* (Brébisson ex Kützing) Rabenhorst
EETE	*Eunotia exigua* var. *tenella* (Grunow) Nörpel & Alles
EIMP	*Eunotia implicata* Nörpel, Lange-Bertalot & Alles
EINC	*Eunotia incisa* Gregory
EMIN	*Eunotia minor* (Kützing) Grunow in Van Heurck
ESOL	*Eunotia soleirolii* (Kützing) Rabenhorst
	Eunotia sp.1
	Eunotia sp.2
	Eunotia sp.3
	Eunotia sp.4
	Eunotia spp. aff. *exigua*
ESUB	*Eunotia subarcuatoides* Alles, Nörpel & Lange-Bertalot
	Fallacia cf. *clepsidroides* Witkowski
FSAP	*Fistulifera saprophila* (Lange-Bertalot & Bonik) Lange-Bertalot

FARC	*Fragilaria arcus* (Ehrenberg) Cleve
FAUT	*Fragilaria austriaca* (Grunow) Lange-Bertalot
*FCAN	*Fragilaria canariensis* Lange-Bertalot
FCAP	*Fragilaria capucina* Desmazières
FCRA	*Fragilaria capucina* var. *radians* (Kützing) Lange-Bertalot
FCRO	*Fragilaria crotonensis* Kitton
	Fragilaria cf. *crotonensis* Kitton
FDEL	*Fragilaria delicatissima* (W. Smith) Lange-Bertalot
FEXI	*Fragilaria exigua* Grunow
FGRA	*Fragilaria gracilis* Østrup
FGRT	*Fragilaria gracilis* Østrup abnormal form
FHEN	*Fragilaria henryi* Lange-Bertalot
FNAN	*Fragilaria nanana* Lange-Bertalot
**FNIT	*Fragilaria nitzschioides* Grunow in Van Heurck
	Fragilaria parva Tuji & D.M. Williams
*FPEM	*Fragilaria perminuta* (Grunow) Lange-Bertalot
FRUM	*Fragilaria rumpens* (Kützing) G.W.F.Carlson
FSOC	*Fragilaria socia* (J.H. Wallace) Lange-Bertalot
FUAN	*Fragilaria ulna* Sippen *angustissima* (Grunow) Lange-Bertalot
FVAU	*Fragilaria vaucheriae* (Kützing) J.B. Petersen
	Fragilaria vaucheriae (Kützing) J.B. Petersen sensu lato
FRAS	*Fragilaria* sp.
GDEC	*Geissleria decussis* (Østrup) Lange-Bertalot & Metzeltin
GESP	*Geissleria* sp.
*GADC	*Gomphonema acidoclinatum* Lange-Bertalot & E. Reichardt
GANG	*Gomphonema angustatum* (Kützing) Rabenhorst
	Gomphonema aff. *angustatum* (Kützing) Rabenhorst 1864
**GBOB	*Gomphonema bourbonense* E. Reichardt
GCLA	*Gomphonema clavatum* Ehrenberg
	Gomphonema cf. *commutatum* Grunow in Van Heurck
GEXL	*Gomphonema exilissimum* (Grunow) Lange-Bertalot & E. Reichardt
	Gomphonema cf. *gracile* Ehrenberg
GIBE	*Gomphonema ibericum* E. Reichardt
GLTC	*Gomphonema italicum Kützing*
GLGN	*Gomphonema lagenula* Kützing
	Gomphonema cf. *lujanense* E. Reichardt & N. Maidana
GMIN	*Gomphonema minutum* (C. Agardh) C. Agardh
GOLI	*Gomphonema olivaceum* (Hornemann) Brébisson
GPAR	*Gomphonema parvulum* (Kützing) Kützing
GPAS	*Gomphonema parvulum* var. *parvulum* f. *saprophilum* Lange-Bertalot & E. Reichardt
GPUM	*Gomphonema pumilum* (Grunow) E. Reichardt & Lange-Bertalot
*GPEL	*Gomphonema pumilum* var. *elegans* E. Reichardt & Lange-Bertalot
*GPRI	*Gomphonema pumilum* var. *rigidum* E. Reichardt & Lange-Bertalot
	Gomphonema cf. *pygmaeum* Kociolek & Stoermer
GRHB	*Gomphonema rhombicum* M. Schmidt
GROS	*Gomphonema rosenstockianum* Lange-Bertalot & E. Reichardt
GTRU	*Gomphonema truncatum* Ehrenberg
GAME	*Gomphonema uniserhombicum* E. Reichardt

	Gomphonema sp.1
	Gomphonema sp.2
	Gomphosphenia aff. *lingulatiformis* (Lange-Bertalot & Reichardt) Lange-Bertalot
**GOAH	*Gomphosphenia oahuensis* (Hustedt) Lange-Bertalot
HLMO	*Halamphora montana* (Krasske) Levkov
HVEN	*Halamphora veneta* (Kützing) Levkov
HCAP	*Hippodonta capitata* (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski
HHUN	*Hippodonta hungarica* (Grunow) Lange-Bertalot, Metzeltin & Witkowski
*HPDA	*Hippodonta pseudoacceptata* (H. Kobayasi) Lange-Bertalot
KCLE	*Karayevia clevei* (Grunow) Bukhtiyarova
KOBG	*Karayevia oblongella* (Østrup) Aboal
KGES	*Kolbesia gessneri* (Hustedt) Aboal
LHUN	*Lemnicola hungarica* (Grunow) Round & Basson
LGOE	*Luticola goeppertiana* (Bleisch in Rabenhorst) D.G. Mann
LMUT	*Luticola mutica* (Kützing) D.G. Mann
	Luticola aff. *mutica* (Kützing) D.G. Mann
**LVCF	*Luticola ventriconfusa* Lange-Bertalot
MPMI	*Mayamaea permitis* (Hustedt) Bruder & Medlin
MVAR	*Melosira varians* C. Agardh
NAAN	*Navicula angusta* Grunow
*NANT	*Navicula antonii* Lange-Bertalot
NCPR	*Navicula capitatoradiata* Germain
NCAR	*Navicula cari* Ehrenberg
**NCTT	*Navicula cataracta-rheni* Lange-Bertalot
NCRY	*Navicula cryptocephala* Kützing
NCTE	*Navicula cryptotenella* Lange-Bertalot
NCTO	*Navicula cryptotenelloides* Lange-Bertalot
NEXI	*Navicula exilis* Kützing
NGER	*Navicula germainii* J.H. Wallace
NGRE	*Navicula gregaria* Donkin
NLAN	*Navicula lanceolata* (C. Agardh) Kützing
NNOT	*Navicula notha* J.H. Wallace
NRAD	*Navicula radiosa* Kützing
NRCH	*Navicula reichardtiana* Lange-Bertalot
NRHY	*Navicula rhynchocephala* Kützing
NROS	*Navicula rostellata* Kützing
*	*Navicula schmassmannii* Hustedt
NSHR	*Navicula schroeteri* F. Meister
NSYM	*Navicula simulata* Manguin
NTPT	*Navicula tripunctata* (O.F. Müller) Bory
NTRV	*Navicula trivialis* Lange-Bertalot
NVEN	*Navicula veneta* Kützing
NACD	*Nitzschia acidoclinata* Lange-Bertalot
NAGI	*Nitzschia agnita* Hustedt
NAMP	*Nitzschia amphibia* Grunow
NIAR	*Nitzschia archibaldii* Lange-Bertalot
NBRE	*Nitzschia brevissima* Grunow

NCPL	*Nitzschia capitellata* Hustedt
NCLA	*Nitzschia clausii* Hantzsch
NDEB	*Nitzschia debilis* (Arnott) Grunow
NDIS	*Nitzschia dissipata* (Kützing) Grunow
*NDIV	*Nitzschia diversa* Hustedt
NFIL	*Nitzschia filiformis* (W. Smith) Van Heurck
NFON	*Nitzschia fonticola* Grunow
NIFR	*Nitzschia frustulum* (Kützing) Grunow
NHAN	*Nitzschia hantzschiana* Rabenhorst
	Nitzschia cf. *incognita* Legler & Krasske
NINC	*Nitzschia inconspicua* Grunow
NMIC	*Nitzschia microcephala* Grunow
NPAL	*Nitzschia palea* (Kützing) W. Smith
NPAE	*Nitzschia paleacea* (Grunow) Grunow
NIPF	*Nitzschia paleaeformis* Hustedt
NIPM	*Nitzschia perminuta* (Grunow) M. Peragallo
	Nitzschia cf. *rectiformis* Hustedt
NZSU	*Nitzschia supralitorea* Lange-Bertalot
NTUB	*Nitzschia tubicola* Grunow
NIVA	*Nitzschia valdestriata* Aleem & Hustedt
NVSA	*Nitzschia vitrea* Norman var. *salinarum* Grunow
	Nitzschia sp.1
	Nitzschia sp.2
	Nitzschia sp.3
*NUIP	*Nupela imperfecta* (Schimanski) Lange-Bertalot
NULA	*Nupela lapidosa* (Krasske) Lange-Bertalot
NUPS	*Nupela* sp.
PFIB	*Peronia fibula* (Brébisson ex Kützing) Ross
PBRE	*Pinnularia brebissonii* (Kützing) Rabenhorst
	Pinnularia cf. *krammeri* Metzeltin
	Pinnularia cf. *obscura* Krasske
PMIC	*Pinnularia microstauron* (Ehrenberg) Cleve
PSBV	*Pinnularia subbrevistriata* Krammer
PSCA	*Pinnularia subcapitata* Gregory
PINS	*Pinnularia* sp.
PDAU	*Planothidium daui* (Foged) Lange-Bertalot
PTDE	*Planothidium delicatulum* (Kützing) Round & Bukhtiyarova sensu lato
PLEN	*Planothidium engelbrechtii* (Cholnoky) Round & Bukhtiyarova
PLFR	*Planothidium frequentissimum* (Lange-Bertalot) Lange-Bertalot
PGRN	*Planothidium granum* (Hohn & Hellerman) Lange-Bertalot
*PHAY	*Planothidium haynaldii* (Schaarschmidt) Lange-Bertalot
PTLA	*Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot
*PLMN	*Planothidium minutissimum* (Krasske) Lange-Bertalot
PRST	*Planothidium rostratum* (Østrup) Lange-Bertalot
PLEV	*Pleurosira laevis* (Ehrenberg) Compère
PMRG	*Psammothidium marginulatum* (Grunow) Bukhtiyarova & Round
	Psammothidium cf. *rechtensis* (Leclercq) Lange-Bertalot
*	*Pseudostaurosira alvareziae* Cejudo-Figueiras, E. Morales & Ector

**PSBR	*Pseudostaurosira brevistriata* var. *capitata* (Héribaud) N.A. Andresen, Stoermer & Kreis
*PSSE	*Pseudostaurosira elliptica* (Schumann) Edlund, Morales & Spaulding
	Pseudostaurosira aff. *polonica* (Witak & Lange-Bertalot) E. Morales & Edlund
PDTS	*Pseudostaurosira* sp.
PUCS	*Punctastriata* sp.
RSIN	*Reimeria sinuata* (Gregory) Kociolek & Stoermer
RUNI	*Reimeria uniseriata* Sala, Guerrero & Ferrario
RABB	*Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot
**	*Rhoicosphenia adriatica* Caput Mihalić & Levkov
RGIB	*Rhopalodia gibba* (Ehrenberg) O. Müller
SEBA	*Sellaphora bacillum* (Ehrenberg) D.G. Mann
SPUP	*Sellaphora pupula* (Kützing) Mereschkowksy
SSEM	*Sellaphora seminulum* (Grunow) D.G. Mann
SCBI	*Staurosira construens* var. *binodis* (Ehrenberg) Hamilton
SSPE	*Staurosira* sp.
SSVE	*Staurosira venter* (Ehrenberg) Cleve & Möller
SPIN	*Staurosirella pinnata* (Ehrenberg) D.M. Williams & Round
SHAN	*Stephanodiscus hantzschii* Grunow
STIN	*Stephanodiscus invisitatus* Hohn & Hellermann
*SNEO	*Stephanodiscus neoastraea* Håkansson & Hickel
SRBA	*Surirella roba* Leclercq
TFLO	*Tabellaria flocculosa* (Roth) Kützing
THUN	*Tryblionella hungarica* (Grunow) D.G. Mann
UBIC	*Ulnaria biceps* (Kützing) Compère
UULN	*Ulnaria ulna* (Nitzsch) Compère

A total of 319 taxa have been inventoried in the 18 reservoirs seasonally studied, from which 185 diatom taxa were present in abundance above 1% in at least one inventory. These 185 taxa belong to 55 genera, from which *Nitzschia* (23 taxa), *Navicula* (18 taxa), *Gomphonema* (12 taxa), *Achnanthidium* (11 taxa) and *Eunotia* (10 taxa) are the most represented. A total of 20 taxa were new records for the country and 7 were new records for the Iberian Peninsula (Table 3.4).

Table 3.4 List of the taxa presented with abundance above 1% in at least one inventory from the studied reservoirs. One asterisk identifies new records for Portugal and two asterisks identify new records for Iberian Peninsula.

Code	**Taxon**
ACAF	*Achnanthidium affine* (Grunow) Czarnecki
ADCT	*Achnanthidium catenatum* (Bílý & Marvan) Lange-Bertalot
*ADDA	*Achnanthidium daonense* (Lange-Bertalot) Lange-Bertalot, O. Monnier & Ector
*ADEU	*Achnanthidium eutrophilum* (Lange-Bertalot) Lange-Bertalot
ADEG	*Achnanthidium exiguum* (Grunow) Czarnecki sensu lato
ADEX	*Achnanthidium exile* (Kützing) Round & Bukhtiyarova
ADMI	*Achnanthidium minutissimum* (Kützing) Czarnecki

ADPY	*Achnanthidium pyrenaicum* (Hustedt) Kobayasi
*ADSB	*Achnanthidium straubianum* (Lange-Bertalot) Lange-Bertalot
ADSH	*Achnanthidium subhudsonis* (Hustedt) H. Kobayasi
ADCS	*Achnanthidium* sp.
ANMN	*Actinocyclus normanii* (Gregory ex Greville) Hustedt
ACOP	*Amphora copulata* (Kützing) Schoeman & Archibald
AINA	*Amphora inariensis* Krammer
AOVA	*Amphora ovalis* (Kützing) Kützing
APED	*Amphora pediculus* (Kützing) Grunow
AFOR	*Asterionella formosa* Hassall
AUAL	*Aulacoseira alpigena* (Grunow) Krammer
AAMB	*Aulacoseira ambigua* (Grunow) Simonsen
**	*Aulacoseira ambigua* f. *japonica* (F. Meister) Tuji & D.M. Williams
AUDI	*Aulacoseira distans* (Ehrenberg) Simonsen
AUGR	*Aulacoseira granulata* (Ehrenberg) Simonsen
AUGA	*Aulacoseira granulata* var. *angustissima* (O. Müller) Simonsen
**	*Aulacoseira pusilla* (F. Meister) Tuji & Houki
AUSU	*Aulacoseira subarctica* (O. Müller) Haworth
*AUTL	*Aulacoseira tenella* (Nygaard) Simonsen
BPAR	*Bacillaria paradoxa* Gmelin
BBRE	*Brachysira brebissonii* Ross in Hartley
BVIT	*Brachysira vitrea* (Grunow) Ross in Hartley
CBAC	*Caloneis bacillum* (Grunow) Cleve
CEUG	*Cocconeis euglypta* Ehrenberg
CLNT	*Cocconeis lineata* Ehrenberg
CPED	*Cocconeis pediculus* Ehrenberg
CDUB	*Cyclostephanos dubius* (Fricke) Round
CATO	*Cyclotella atomus* Hustedt
CMEN	*Cyclotella meneghiniana* Kützing
COCE	*Cyclotella ocellata* Pantocsek
*CCMP	*Cymbella compacta* Østrup
CAEX	*Cymbella excisa* Kützing
**CNLP	*Cymbella neoleptoceros* Krammer
**CPPV	*Cymbella perparva* Krammer
CTGL	*Cymbella turgidula* Grunow
CBNA	*Cymbopleura naviculiformis* (Auerswald ex Heiberg) Krammer
DKUE	*Denticula kuetzingii* Grunow
DTEN	*Denticula tenuis* Kützing
DCOF	*Diadesmis confervacea* Kützing
DMES	*Diatoma mesodon* (Ehrenberg) Kützing
DVUL	*Diatoma vulgaris* Bory
DPST	*Discostella pseudostelligera* (Hustedt) Houk & Klee
DSTE	*Discostella stelligera* (Cleve & Grunow) Houk & Klee
*ENLB	*Encyonema lange-bertalotii* Krammer
ENMI	*Encyonema minutum* (Hilse in Rabenhorst) D.G. Mann
ENNG	*Encyonema neogracile* Krammer
EPRO	*Encyonema prostratum* (Berkeley) Kützing
ENRO	*Encyonema rostratum* Krammer

ESLE	*Encyonema silesiacum* (Bleisch in Rabenhorst) D.G. Mann
ENVE	*Encyonema ventricosum* (C. Agardh) Grunow
EAQL	*Encyonopsis aequalis* (W. Smith) Krammer
**	*Encyonopsis horticola* Van de Vijver & Compère
*ECPM	*Encyonopsis minuta* Krammer & E. Reichardt
*ESUM	*Encyonopsis subminuta* Krammer & E. Reichardt
ECKR	*Encyonopsis tavirana* Krammer
EOMI	*Eolimna minima* (Grunow) Lange-Bertalot
ESBM	*Eolimna subminuscula* (Manguin) Moser, Lange-Bertalot & Metzeltin
ETUR	*Epithemia turgida* (Ehrenberg) Kützing
EEXI	*Eunotia exigua* (Brébisson ex Kützing) Rabenhorst
EUIN	*Eunotia intermedia* (Krasske ex Hustedt) Nörpel & Lange-Bertalot
EMIN	*Eunotia minor* (Kützing) Grunow in Van Heurck
EUPA	*Eunotia paludosa* Grunow in Van Heurck
EPUN	*Eunotia pectinalis* var. *undulata* (Ralfs) Rabenhorst
ERHO	*Eunotia rhomboidea* Hustedt
ESOL	*Eunotia soleirolii* (Kützing) Rabenhorst
ESUB	*Eunotia subarcuatoides* Alles, Nörpel & Lange-Bertalot
EUNS	*Eunotia* sp.
FSAP	*Fistulifera saprophila* (Lange-Bertalot & Bonik) Lange-Bertalot
FARC	*Fragilaria arcus* (Ehrenberg) Cleve
FBID	*Fragilaria bidens* Heiberg
FCAP	*Fragilaria capucina* Desmazières
FCRO	*Fragilaria crotonensis* Kitton
FGRA	*Fragilaria gracilis* Østrup
	Fragilaria cf. *nanana* Lange-Bertalot
	Fragilaria parva Tuji & D.M. Williams
FRUM	*Fragilaria rumpens* (Kützing) G.W.F.Carlson
FVAU	*Fragilaria vaucheriae* (Kützing) J.B. Petersen
FRAS	*Fragilaria* sp.
FCRS	*Frustulia crassinervia* (Brébisson) Lange-Bertalot & Krammer
GDEC	*Geissleria decussis* (Østrup) Lange-Bertalot & Metzeltin
*GMMI	*Gomphoneis minuta* (Stone) Kociolek & Stoermer
	Gomphonema sp.
GEXL	*Gomphonema exilissimum* (Grunow) Lange-Bertalot & E. Reichardt
	Gomphonema cf. *gracile* Ehrenberg
	Gomphonema cf. *lange-bertalotii* E. Reichardt
*GLAT	*Gomphonema lateripunctatum* E. Reichardt & Lange-Bertalot
GMIN	*Gomphonema minutum* (C. Agardh) C. Agardh
GPAR	*Gomphonema parvulum* (Kützing) Kützing
GPSA	*Gomphonema pseudoaugur* Lange-Bertalot
GPUM	*Gomphonema pumilum* (Grunow) E. Reichardt & Lange-Bertalot
	Gomphonema cf. *pumilum* (Grunow) E. Reichardt & Lange-Bertalot
GRHO	*Gomphonema rhombicum* Fricke
GROS	*Gomphonema rosenstockianum* Lange-Bertalot & E. Reichardt
HLMO	*Halamphora montana* (Krasske) Levkov
HOLI	*Halamphora oligotraphenta* (Lange-Bertalot) Levkov

HVEN	*Halamphora veneta* (Kützing) Levkov
HABU	*Hantzschia abundans* Lange-Bertalot
HAMP	*Hantzschia amphioxys* (Ehrenberg) Grunow
HCAP	*Hippodonta capitata* (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski
KCLE	*Karayevia clevei* (Grunow) Bukhtiyarova
KOBG	*Karayevia oblongella* (Østrup) Aboal
LGOE	*Luticola goeppertiana* (Bleisch in Rabenhorst) D.G. Mann
LMUT	*Luticola mutica* (Kützing) D.G. Mann
MVAR	*Melosira varians* C. Agardh
MCIR	*Meridion circulare* (Greville) C. Agardh
NAAN	*Navicula angusta* Grunow
*NANT	*Navicula antonii* Lange-Bertalot
NCPR	*Navicula capitatoradiata* Germain
NCRY	*Navicula cryptocephala* Kützing
NCTE	*Navicula cryptotenella* Lange-Bertalot
NEXI	*Navicula exilis* Kützing
NGRE	*Navicula gregaria* Donkin
NHMD	*Navicula heimansioides* Lange-Bertalot
NLST	*Navicula leptostriata* Jørgensen
NNOT	*Navicula notha* J.H. Wallace
NRAD	*Navicula radiosa* Kützing
NRCH	*Navicula reichardtiana* Lange-Bertalot
NRHY	*Navicula rhynchocephala* Kützing
NROS	*Navicula rostellata* Kützing
NSAL	*Navicula salinarum* Grunow
NTPT	*Navicula tripunctata* (O.F. Müller) Bory
NVEN	*Navicula veneta* Kützing
NVRO	*Navicula viridula* (Kützing) Ehrenberg var. *rostellata* (Kützing) Cleve
NACI	*Nitzschia acicularis* (Kützing) W. Smith
NACN	*Nitzschia acidoclinata* Lange-Bertalot
NAGN	*Nitzschia agnita* Hustedt
NAMP	*Nitzschia amphibia* Grunow
NBRE	*Nitzschia brevissima* Grunow
NCLA	*Nitzschia clausii* Hantzsch
NDIS	*Nitzschia dissipata* (Kützing) Grunow
NFON	*Nitzschia fonticola* Grunow
NIFR	*Nitzschia frustulum* (Kützing) Grunow
*NGES	*Nitzschia gessneri* Hustedt
NIGR	*Nitzschia gracilis* Hantzsch
NINC	*Nitzschia inconspicua* Grunow
NLIN	*Nitzschia linearis* (C. Agardh) W. Smith
NMIC	*Nitzschia microcephala* Grunow
NNAN	*Nitzschia nana* Grunow in Van Heurck
NPAL	*Nitzschia palea* (Kützing) W. Smith
NPAD	*Nitzschia palea* var. *debilis* (Kützing) Grunow
NPAE	*Nitzschia paleacea* (Grunow) Grunow
NIPM	*Nitzschia perminuta* (Grunow) M. Peragallo
NREC	*Nitzschia recta* Hantzsch in Rabenhorst

NZSU	*Nitzschia supralitorea* Lange-Bertalot
	Nitzschia cf. *tropica* Hustedt
NZSS	*Nitzschia* sp.
OPES	*Opephora* sp.
PFIB	*Peronia fibula* (Brébisson ex Kützing) Ross
PSCA	*Pinnularia subcapitata* Gregory
PSRO	*Pinnularia subrostrata* (A. Cleve) Cleve-Euler
PCLT	*Placoneis clementis* (Grunow) E.J. Cox
PPLC	*Placoneis placentula* (Ehrenberg) Heinzerling
PNCO	*Planothidium conspicuum* (Ant. Mayer) E. Morales 2006
PTDE	*Planothidium delicatulum* (Kützing) Round & Bukhtiyarova sensu lato
PLFR	*Planothidium frequentissimum* (Lange-Bertalot) Lange-Bertalot
PGRN	*Planothidium granum* (Hohn & Hellerman) Lange-Bertalot
PTLA	*Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot
PRST	*Planothidium rostratum* (Østrup) Lange-Bertalot
PCHL	*Psammothidium chlidanos* (Hohn & Hellerman) Lange-Bertalot
PSAT	*Psammothidium subatomoides* (Hustedt) Bukhtiyarova & Round
**PBCA	*Pseudostaurosira brevistriata* var. *capitata* (Héribaud) N.A. Andresen, Stoermer & Kreis
PSSE	*Pseudostaurosira elliptica* (Schumann) Edlund, E. Morales & Spaulding
PSSB	*Pseudostaurosira subsalina* (Hustedt) E. Morales
PUCS	*Punctastriata* sp.
RABB	*Rhoicosphenia abbreviata* (C.Agardh) Lange-Bertalot
SSEM	*Sellaphora seminulum* (Grunow) D.G. Mann
STAN	*Stauroneis anceps* Ehrenberg
SCON	*Staurosira construens* Ehrenberg
SCBI	*Staurosira construens* var. *binodis* (Ehrenberg) Hamilton
SSVE	*Staurosira venter* (Ehrenberg) Cleve & Möller
SPIN	*Staurosirella pinnata* (Ehrenberg) D.M. Williams & Round
SSSP	*Staurosirella* spp.
STDE	*Stenopterobia delicatissima* (Lewis) Brébisson ex Van Heurck
SHAN	*Stephanodiscus hantzschii* Grunow
*SNEO	*Stephanodiscus neoastraea* Håkansson & Hickel
SANG	*Surirella angusta* Kützing
TFLO	*Tabellaria flocculosa* (Roth) Kützing
**TPFL	*Tabellaria pseudoflocculosa* H. Kobayasi ex Mayama
UULN	*Ulnaria ulna* (Nitzsch) Compère

In total, 49 diatom taxa are new records for Portugal and 14 are new records for the Iberian Peninsula, as can be seen in the Table 3.5, where all the new records found within this study are compiled.

Table 3.5 List with all the new records for Portugal and for the Iberian Peninsula. One asterisk identifies new records for Portugal and two asterisks identify new records for Iberian Peninsula.

Code	**Taxon**
*ADDA	*Achnanthidium daonense* (Lange-Bertalot) Lange-Bertalot, O. Monnier & Ector

*ADEU	*Achnanthidium eutrophilum* (Lange-Bertalot) Lange-Bertalot
**AHMI	*Achnanthes helvetica* var. *minor* Flower & Jones 1989
*ADAM	*Achnanthidium atomoides* Monnier, Lange-Bertalot & Ector
*ADDA	*Achnanthidium daonense* (Lange-Bertalot) Lange-Bertalot, Monnier & Ector
*ADEU	*Achnanthidium eutrophilum* (Lange-Bertalot) Lange-Bertalot
*ADRI	*Achnanthidium rivulare* Potapova & Ponader
*ADSB	*Achnanthidium straubianum* (Lange-Bertalot) Lange-Bertalot
*AMID	*Amphora indistincta* Levkov
*ALGT	*Amphora lange-bertalotii* var. *tenuis* Levkov & Metzeltin
**	*Aulacoseira ambigua* f. *japonica* (F. Meister) Tuji & D.M. Williams
**AUPU	*Aulacoseira pusilla* (F. Meister) Tuji & Houki
*AUTL	*Aulacoseira tenella* (Nygaard) Simonsen
*CNTH	*Cocconeis neothumensis* Krammer
*CCMP	*Cymbella compacta* Østrup
**CNLP	*Cymbella neoleptoceros* Krammer
**CPPV	*Cymbella perparva* Krammer
*DSEP	*Diploneis separanda* Lange-Bertalot
*ENLB	*Encyonema lange-bertalotii* Krammer
**	*Encyonopsis horticola* Van de Vijver & Compère
*ECPM	*Encyonopsis minuta* Krammer & E. Reichardt
*ESUM	*Encyonopsis subminuta* Krammer & E. Reichardt
*EOCO	*Eolimna comperei* Ector, Coste & Iserentant
*FCAN	*Fragilaria canariensis* Lange-Bertalot
**FNIT	*Fragilaria nitzschioides* Grunow in Van Heurck
*FPEM	*Fragilaria perminuta* (Grunow) Lange-Bertalot
*GMMI	*Gomphoneis minuta* (Stone) Kociolek & Stoermer
*GADC	*Gomphonema acidoclinatum* Lange-Bertalot & E. Reichardt
**GBOB	*Gomphonema bourbonense* E. Reichardt
*GLAT	*Gomphonema lateripunctatum* E. Reichardt & Lange-Bertalot
*GPEL	*Gomphonema pumilum* var. *elegans* E. Reichardt & Lange-Bertalot
*GPRI	*Gomphonema pumilum* var. *rigidum* E. Reichardt & Lange-Bertalot
**GOAH	*Gomphosphenia oahuensis* (Hustedt) Lange-Bertalot
*HPDA	*Hippodonta pseudoacceptata* (H. Kobayasi) Lange-Bertalot
**LVCF	*Luticola ventriconfusa* Lange-Bertalot
*NANT	*Navicula antonii* Lange-Bertalot
**NCTT	*Navicula cataracta-rheni* Lange-Bertalot
*	*Navicula schmassmannii* Hustedt
*NDIV	*Nitzschia diversa* Hustedt
*NGES	*Nitzschia gessneri* Hustedt
*NUIP	*Nupela imperfecta* (Schimanski) Lange-Bertalot
*PHAY	*Planothidium haynaldii* (Schaarschmidt) Lange-Bertalot
*PLMN	*Planothidium minutissimum* (Krasske) Lange-Bertalot
*	*Pseudostaurosira alvareziae* Cejudo-Figueiras, E. Morales & Ector
**PSBR	*Pseudostaurosira brevistriata* var. *capitata* (Héribaud) N.A. Andresen, Stoermer & R.G. Kreis
*PSSE	*Pseudostaurosira elliptica* (Schumann) Edlund, Morales & Spaulding
**	*Rhoicosphenia adriatica* Caput Mihalić & Levkov
*SNEO	*Stephanodiscus neoastraea* Håkansson & Hickel
**TPFL	*Tabellaria pseudoflocculosa H. Kobayasi ex Mayama*

The high number of new records for the country (10.7% of the total taxa identified from the reservoirs and 14.0% of the total taxa identified from the watercourses) proves that Portuguese freshwater diatom flora is still undersurveyed and further studies are needed to increase the knowledge about its high diversity.

This high floristic diversity is comparable to that of other studies made in different regions of the Iberian Peninsula, such as the Douro basin (Spanish part), where 494 diatom taxa have been identified with abundance above 1% in the 636 samples analysed (BLANCO et al. 2010). Also the Confederación Hidrográfica del Ebro (2005) recorded 347 taxa in the 190 samples analysed in 2005. In Portugal, ALMEIDA (1998) recorded 370 diatom taxa in 18 sampling sites monthly sampled during eighteen months and located in the Vouga watershed in the Centre of Portugal. Furthermore, only in the basins of the Centre of Portugal (Mondego, Vouga and Lis) a total of 176 diatom taxa have been identified in samples collected in 2004 and 2005 (FEIO et al. 2007). In Azores, 276 diatom taxa have been identified in the study of 23 lakes between 2001 and 2002 (GONÇALVES 2008).

This diversity is probably so high due to the heterogeneity of the territory sampled, since the whole country has been considered in this study. Portugal is known by its heterogeneity in terms of geology, orography, altitude, climate and hydrology. This heterogeneity was noticeable in the 27 river types initially defined by the National Water Institute through the application of the system B of the Water Framework Directive in the country (MORAIS et al. 2009a).

There is a high number (49) of new records for the country (listed in Table 3.5), according to the catalogue with the diatom taxa cited for Portugal and partially presented in the chapter 2. From these, 14 are new records for the Iberian Peninsula, according to the analysis of the compilation published by ABOAL et al. (2003) and recent publications, such as, GOMÀ et al. (2005), BLANCO et al. (2008), GARCÍA et al. (2008) and BLANCO et al. (2010). This high number of new records is probably due to the continuous splitting of species complexes that were previously considered together, such as the *Encyonopsis microcephala* (Grunow) Krammer complex published in KRAMMER (1997). Furthermore, the thorough study of some genera has highly increased the number of taxa (e.g. the five volumes of the series Diatoms of Europe). In addition, the detailed study of some specific regions (e.g. the series Iconographia Diatomologica) revealed several novelties for the diatom flora. Furthermore, this trend follows the suggestion that microorganisms exhibit a biogeography (MARTINY et al. 2006) and that regional patterns in microbial diversity are consistent with those observed in macroorganisms (SMITH et al. 2005). Also VYVERMAN et al. (2007) proved that historical processes (e.g. dispersion and migration, colonization and extinction) constrain global patterns in regional and local diatom diversity. Which is also in accordance with the distinct provinciality and high levels of apparent endemism in the isolated diatom floras of the Australian, Antarctic and Sub-Antarctic freshwaters (VYVERMAN et al. 1998; SABBE et al. 2003; VAN DE VIJVER et al. 2005).

In spite of these recent advances, the number of diatom taxa known actually is probably being underestimated, as pointed out by MANN (1999) who states that a consilience of evidence from morphology, genetic data, mating systems, physiology, ecology and crossing behaviour suggests that species boundaries have traditionally been drawn too broadly. Recent molecular studies have showed

that many phenotype-based species contained two or more genetically distinct demes, as was confirmed for *Navicula cryptocephala* Kützing which presents pseudocryptic diversity (POULIČKOVÁ et al. 2010). The widespread use of concepts as "cryptic" and "pseudocryptic" species lead to the inclusion of the explanation proposed by MANN & EVANS (2007), according to which should be considered "pseudocryptic" the species that are initially distinguished on the basis of molecular or mating data but are found subsequently to exhibit small morphological differences, being therefore those species that are merely difficult to identify; "semicryptic" are species that can be told apart only when the observer has both morphological data and provenance information; and "cryptic" are species that cannot be separated morphologically under any circunstances. One good example of semicryptic freshwater species complex is the *Sellaphora pupula* complex, which is among the best studied complexes (e.g. MANN 1989; BEHNKE et al. 2004; MANN et al. 2008). There is consequently an urgent need of an establishment of species definitions that are both meaningful and practical (MANN & EVANS 2007).

During the last decades have just been performed few detailed studies on the occurrence of tropical or exotic algae in Western Europe (COSTE & ECTOR 2000). Nevertheless, this information can be valuable in terms of systematic or biogeography (KOCIOLEK & SPAULDING 2000) and can also help to define endemisms (MOSER et al. 1998). Among the taxa identified within the present study some species considered exotic, or with few records apart from their original locality, have been found, such as *Achnanthidium subhudsonis* (Hustedt) H. Kobayasi, *A. catenatum* (J. Bílý & Marvan) Lange-Bertalot, *A. rivulare* Potapova & Ponader, *Diadesmis confervacea* Kützing, *Eolimna comperei* Ector, Coste & Iserentant, *Hippodonta pseudoacceptata* (H. Kobayasi) Lange-Bertalot, *Gomphoneis minuta* (Stone) Kociolek & Stoermer, *Gomphonema bourbonense* E. Reichardt, *Gomphonema lagenula* Kützing, *Gomphonema pumilum* var. *rigidum* E. Reichardt & Lange-Bertalot and *Gomphosphenia oahuensis* (Hustedt) Lange-Bertalot.

***Achnanthidium subhudsonis* (Hustedt) H. Kobayasi** (Plate 179, Figs 86-113; Plate 181, Figs 1-5) is currently widespread throughout the whole country, although it is less frequent in the south, with only few records in the Guadiana watershed. This taxon was found in high abundance in the Côa River (Douro basin), in Seixo do Côa and Azêvo it reached abundance above 50%. The taxon has only been very recently recorded in the country by FEIO et al. (2007), NUNES (2007) and INAG (2008), which is in accordance with the suggestion that this is an invasive species, being only recently identified in French and Spanish watercourses (COSTE & ECTOR 2000; BLANCO et al. 2010).

***Achnanthidium catenatum* (J. Bílý & Marvan) Lange-Bertalot** (Plate 168, Figs 75-128; Plate 171, Figs 1-4) is distributed throughout the country, although not in high abundance. The site where it was present with the highest abundance was in Levira River by the locality of Laborins (Vouga basin). Previously it has only been cited by ALMEIDA (1998), who identified it also in the Levira River (municipality of Oliveira do Bairro). In reservoirs it reached the highest abundance in Santa Luzia Reservoir in autumn, even if it was also present in the other seasons. It was also present in several other reservoirs, like Marateca Reservoir although not in such high abundance.

***Achnanthidium rivulare* Potapova & Ponader** (Plate 179, Figs 1-61; Plate 180, Figs 1-5) occurred in the Mondego and Douro basins. It was present with the highest abundance in the Anços River (Mondego basin) by the locality of Redinha (70.8%). Additionally it was also found with high abundance in Alva River, also belonging to the Mondego basin (12.7%), and in the Caravelas stream (32.4%), Rabaçal River (67.0%), in Tua River (24.3%) and in Tuela River (50.7%), all part of the Douro basin. Apart from these sites it was present in several samples from the Douro basin, although with lower abundance. On the other hand, it was not found in the samples from reservoirs. This taxon was recently recorded (BLANCO et al. 2010) by the first time outside of the United States of America, from where it was described by PONADER & POTAPOVA (2004). It was recorded by BLANCO et al. (2010) for the Spanish part of the Douro basin, mainly in streams with siliceous substrata, which is in accordance with the sites in Portugal where it was identified, the majority located in the Douro basin.

***Diadesmis confervacea* Kützing** (Plate 195, Figs 1-20) is a species originary from the tropical regions (OKUNO 1974), nevertheless it is nowadays present in several temperate regions allowing it to be considered a cosmopolite species (KRAMMER & LANGE-BERTALOT 1986). It was identified in few sites within this study, being its highest abundance in Nisa Stream (Tejo basin) (15.8%), being present in other watercourses but with low abundance. In reservoirs it was present in abundance above 1% only in Torrão Reservoir (Tâmega River, Douro basin) (11.4%). Previously this species has only been recorded in Portugal by CALADO (1990) and INAG (2008), but without precise indication of the location.

***Eolimna comperei* Ector, Coste & Iserentant** (Plate 207, Figs 61-93; Plate 208, Figs 1-4) is a taxon recently described from France by Coste & Ector (2000). It was identified with abundance above 1% only in Rabaçal River (9.1%) and Tâmega River (13.1%), both belonging to the Douro basin and these are the first records of this taxon for the country. According to BLANCO et al. (2010), up to date it has only been found in France and Spain. Probably it has a wider distribution, nevertheless its resemblance with the raphe valves of *Achnanthidium subhudsonis* may be masking its real distribution.

***Hippodonta pseudoacceptata* (H. Kobayasi) Lange-Bertalot** (Plate 241, Figs 43-80; Plate 243, Figs 1-4) is here recorded for the first time for the country. It was found with abundance above 1% only in the following sites: Porto de Lagos, Boina Stream (Ribeiras do Algarve basin) (2.5%), São Martinho Stream (Sado basin) (1.4%), Chamusca, Tejo River (Tejo basin) (3.4%) and Torto River (Douro basin) (6.7%). Even if this taxon has been found in few sites, they are distributed throughout the whole country, what suggests a cosmopolite distribution. This taxon was recently subject of a detailed study, which allowed the confirmation of its taxonomical identity (BLANCO et al. in press), since it was posing identification problems for some time. It has been described from Japan by H. KOBAYASI in KOBAYASI & MAYAMA (1986) and this constitutes the second record of this taxon outside Japan, since the first one was in the Spanish part of the Douro basin (BLANCO et al. 2010).

***Gomphoneis minuta* (Stone) Kociolek & Stoermer** (Plate 105, Figs 1-4) was only identified in the Régua reservoir (Douro river), in spring (1.6%) and in summer (1.2%); and in Malhadais (Mosteiró River, Douro basin) (1.0%). It was previously only identified in the Almonda River (Tejo basin) by

OLIVEIRA & CALDAS (1970) under the name of *Gomphoneis herculeana* (Ehrenberg) Cleve (but without any illustration). Nevertheless it is widespread in Spain, namely in the Spanish part of the Douro basin (BLANCO et al. 2010), in the Ter (COSTE & ECTOR 2000), in the Tordera (GOMÀ 2004) and in the Segre basins (GOMÀ et al. 2005), all located in Catalonia. According to COSTE & ECTOR (2000), this taxon is nowadays enlarging its distribution towards the south.

***Gomphonema bourbonense* E. Reichardt** (Plate 116, Figs 40-67) was first described by REICHARDT (1997) in a revision of the *Gomphonema pumilum* complex. It was present within this study in only in one site, Marmelar stream (Guadiana basin) (4.7%). This taxon is probably more widespread in the country but it can be easily misidentified with *Gomphonema pumilum* var. *rigidum* E. Reichardt & Lange-Bertalot, since the only difference is the presence of punctae in the mantle, that can only be seen in girdle view.

***Gomphonema lagenula* Kützing** (Plate 108, Figs 41-64) is considered to be a subcosmopolite taxon, typical for tropical regions (BLANCO et al. 2010). It has been found with abundance above 1% only in two sampling sites, Porto das Vacas, Zêzere River (Tejo basin) (2.0%) and Valmaior, Caima River (Vouga basin) (3.6%). This taxon was only recorded before in Portugal (Porto) by COLMEIRO (1889), in one of the first studies comprising freshwater diatoms from the country. Afterwards it was not cited, probably due to possible misidentifications with *G. parvulum* (Kützing) Kützing that was described afterwards.

***Gomphonema pumilum* var. *rigidum* E. Reichardt & Lange-Bertalot** (Plate 113, Figs 51-65; Plate 116, Figs 1-39) is a taxon frequent in watercourses in the south of Portugal and was the dominant species in Odivelas stream (Sado basin) (56.7%). This constitutes the first record of this taxon for the country, as well as of ***Gomphonema pumilum* var. *elegans* E. Reichardt & Lange-Bertalot** (Plate 113, Figs 33-50; Plate 115, Figs 1, 2), however the latter is not so widely distributed. It was present with abundance above 1% only in two sampling sites, Ameixial (Guadiana basin) (9.9%) and in Valmar Stream (Mondego basin) (14.1%). These taxa are being recorded for the first time probably due to the recent separation of the *Gomphonema pumilum* species complex by REICHARDT (1997) and their morphological similarities, nevertheless their ecological preferences are distinct, which constitutes the reason for their separation within this study. Nevertheless, *Gomphonema pumilum* (Grunow) E. Reichardt & Lange-Bertalot has been cited by several authors and for the whole country.

***Gomphosphenia oahuensis* (Hustedt) Lange-Bertalot** (Plate 133, Figs 43-60; Plate 136, Figs 1-4) is undoubtly considered a subtropical taxon by COSTE & ECTOR (2000), since it was first described from Hawai. In Europe it has been recorded, in low abundance, from the Adour River in France by COSTE & ECTOR (2000), associated with halophilous taxa such as *Nitzschia amplectens* Hustedt and *N. brevissima* Grunow. In Portugal this taxon was only found in one site, Retorta, Ave River (Ave basin), with a high abundance (22.4%). The community was mainly composed by taxa tolerant to organic pollution, such as *Nitzschia inconspicua* (36.9%), *Luticola mutica* (6.5%), *Eolimna minima* (5.2%), *Navicula gregaria* (4.7%), *Sellaphora seminulum* (2.4%), *Nitzschia amphibia* (2.2%) and *N. palea* (1.2%). It is relevant that in this sample there was also present a *Nupela* species (1.2%) that was not possible to identify according to the available bibliography and is probably a new taxon.

An interesting result is the absence, during this study, of *Didymosphenia geminata* (Lyngbye) M. Schmidt, a diatom that is nowadays recognized as one of the most of the most harmful invasive organisms in lotic systems worldwide (BLANCO & ECTOR 2009; WHITTON et al. 2009). This species is native to northern-latitude lakes and streams and is considered to be restricted to low nutrient, low-temperature habitats with little anthropogenic impact. However, in recent years, its distribution has changed and its geographic area is being expanded, as can be seen in the distribution maps with current and fossil records presented by BLANCO & ECTOR (2009) and WHITTON et al. (2009). This species has only been identified in Portugal by ZIMMERMANN (1909) in the Ave River in the north of the country. It has however been found in summer 2008 in several watercourses belonging to the spanish part of the Douro basin (BLANCO et al. 2010), therefore it is highly probable that it can be already present in Portugal, since the present study is based in samples collected in 2006 and 2007, or that it can reach the country in a near future. This species was not recorded in the present study despite the fact that all diatom colonies macroscopically visible in the field were also investigated by light microscopy.

Apart of these, it is interesting to notice that the following taxa were recorded for the first time for the Iberian Peninsula, as can be seen in Table 3.5: *Achnanthes helvetica* var. *minor* Flower & Jones, *Aulacoseira ambigua* f. *japonica* (F. Meister) Tuji & D.M. Williams, *A. pusilla* (F. Meister) Tuji & Houki, *Cymbella neoleptoceros* Krammer, *Cymbella perparva* Krammer, *Encyonopsis horticola* Van de Vijver & Compère, *Fragilaria nitzschioides* Grunow in Van Heurck, *Luticola ventriconfusa* Lange-Bertalot, *Navicula cataracta-rheni* Lange-Bertalot, *Pseudostaurosira brevistriata* var. *capitata* (Héribaud) N.A. Andresen, Stoermer & Kreis, *Rhoicosphenia adriatica* Caput Mihalić & Levkov and *Tabellaria pseudoflocculosa* H. Kobayasi ex Mayama.

***Achnanthes helvetica* var. *minor* Flower & Jones** (Plate 182, Figs 1-28; Plate 183, Figs 1-4) is a taxon described by FLOWER & JONES (1989) from Lochnagar, Carngorms, Scotland. This taxon was present with abundance above 1% in 7 sites in the centre and north of Portugal, belonging to the Mondego, Vouga, Douro and Lima basins (Outeiro das Cabras, Âncora River (10.8%), Daires, Pequeno Sream (6.7%), Barrela, Pinhão River (3.9%), Sub-Igreja, Vez River (2.4%), Manhouce, Manhouce Stream (2.0%), Sabugueiro, Fervença Stream (1.9%) and Bucos Além Rio, Carvoeiras Stream (1.74%)). According to FLOWER & JONES (1989), this variety has been found in low frequencies in the epilithon and epipsammon in several Cairngorn lakes and occured in the surface sediments of 24 upland oligotrophic Scottish and Welsh lakes with an abundance weighted mean pH of 5.1. FLOWER & JONES (1989) distinguish this variety from *Achnanthes helvetica* Hustedt by the unclear punctuation of the rapheless valve, the smaller size and the oval rather than elliptical valve outline. The same taxon has however been illustrated as *Achnanthes helvetica* Hustedt by GERMAIN 1981 (p. 112, pl. 12, fig. 3-5) and by KRAMMER & LANGE-BERTALOT 1991b (pl. 10, fig. 20-27), among others.

***Aulacoseira ambigua* f. *japonica* (F. Meister) Tuji & D.M. Williams** (Plate 4, Figs 16-29) was only identified in the reservoirs of Fratel (in spring – 7.2%, summer – 2.5% and autumn – 1.2%) and Pocinho (spring - 3.4%). Additionally it was only found in Belver (Tejo River) (1.2%), which is probably

due to the fact that sampling site is located downstream of the Belver Reservoir and this is a planktonic species. This taxon was originally described from Japan by MEISTER as *Melosira japonica* and recently recombined by TUJI & WILLIAMS (2007) as *Aulacoseira ambigua* f. *japonica* (F. Meister) Tuji & D.M. Williams. According to these authors it is important to distinguish this variety since the form of the colonies (straight or spiral) correspond to different ecological occurrences, with the spiral forms accuring in eutrophic environments, which is in accordance with the present results, since this species occurred in eutrophic reservoirs.

***Aulacoseira pusilla* (F. Meister) Tuji & Houki** (Plate 4, Figs 8-15; Plate 5, Figs 4-6; Plate 6, Figs 1-22) was identified in several reservoirs widespread throughout the country but normally with low relative abundance, with a maximum in Belver reservoir (4.7%). Furthermore, it was present in only two rivers: Casal Rei, Zêzere River (Tejo basin) (8.7%) and Senra, Lima River (Lima basin) (10.1%). This taxon was originally described from Japan as *Melosira pusilla* F. Meister and later recombined by TUJI & HOUKI (2004), who consider it as a synonym of *Aulacoseira subborealis* (Nygaard) Denys, Muylaert & Krammer in DENYS et al. (2003). It is common in Japanese eutrophic lakes, ponds and reservoirs (TUJI & WILLIAMS 2007). Taking into the account the synonymy with *A. subborealis*, this taxon has been found in sediments from several lakes in Sweden and Belgium and recent observations have detected it in the Schelde estuary (Belgium/The Netherlands), in lakes in the French Massif Central, in The Netherlands (catchment areas of the Rivers Maas and Rijn) and in Belgium (DENYS et al. 2003). This taxon has been considered to have a preference for alkaline and nutrient rich conditions, which is into accordance with its presence in the sediment record of the shallow Blankaart Reservoir (Belgium), a site that underwent severe eutrophication and pollution in the course of the 20th century; furthermore, it was also found in several eutrophic lakes in the catchment area of the Rivers Maas and Rijn in The Netherlands; and in surface sediment samples from 17 eutrophic ponds and oxbow lakes in Belgium (DENYS et al. 2003).

***Cymbella neoleptoceros* Krammer** (Plate 85, Figs 1-9; Plate 86, Figs 1-5) was present only in one sampling site in the whole database, Valeira Reservoir (located in the Douro River) in the Summer campaign with abundance of 8.9%. This is a taxon recently described by Krammer in KRAMMER (2002), which is probably why it is not yet recorded for the Iberian Peninsula.

***Cymbella perparva* Krammer** (Plate 77, Figs 9-26; Plate 78, Figs 1-5; Plate 79, Figs 15-17) was present both in reservoirs and watercourses. It was identified in Montargil Reservoir (Spring – 10.4%; Autumn – 1.7%) and in Crestuma Reservoir (Summer – 2.2%). In watercourses it was found in Felgar, Sabor River (1.5%), Junqueira, Maçãs River (3.8%) and in Azinhal de Mouros, Vascão Stream (1.7%), that belong to the Douro and Guadiana basins. The fact that it was present in reservoirs and watercourses belonging to basins from different regions of the country can mean that this is a taxon that is more widespread throughout the country.

***Encyonopsis horticola* Van de Vijver & Compère** (Plate 100, Figs 58-78; Plate 103, Figs 1-4) was present in abundance above 1% only in Odeleite Reservoir, Odeleite Stream – Summer (10.3%). This is a taxon recently described from a small pool in the National Botanic Garden of Belgium. It is similar in valve outline to *E. krammeri* E. Reichardt, nevertheless it can be distinguished from the latter by the

lack of the typical shift in stria orientation, by its higher number of striae in10 µm (28-30 vs. 26-28.5) and a different areola shape (transapically enlarged vs. rounded) (VAN DE VIJVER et al. 2009).

***Fragilaria nitzschioides* Grunow in Van Heurck** (Plate 38, Figs 36-59) was found in 7 sites with abundance above 1%: Cinco Vilas, Côa River (28.5%), Real, Docim Stream (3.5%), Sabugueiro, Fervença Stream (1.9%), Soutelo, Coura River (1.7%), Guilhofrei, Ave River (1.5%), Pêgo, Tejo River (1.5%) and Daires, Pequeno Sream (1.2%). This taxon can probably be misindentified with *Fragilariforma virescens* (Ralfs) Williams & Round, but can be distinguished from the latter by the valve outline and by the smaller dimensions, especially the width (ca. 6-10 µm vs. 3.6-6 µm in KRAMMER & LANGE-BERTALOT 1991a). Further studies should be carried out about this taxon, if possible with the analysis of the type material, to confirm its possible affiliation to the genus *Fragilariforma*.

***Luticola ventriconfusa* Lange-Bertalot** (Plate 199, Figs 37-69; Plate 200, Figs 1-4) is widespread throughout the country, being present in the Guadiana, Tejo, Mira and Douro watersheds. It was the dominant taxon in Belver, Tejo River (41.0%) and in Miranda, Douro River (64.5%).

***Navicula cataracta-rheni* Lange-Bertalot** (Plate 223, Figs 1-7) is a taxon described by LANGE-BERTALOT (1993) and is widespread in the Douro and Mondego basins, reaching its highest abundance in Valezim Stream (Mondego basin) (12.5%), in Coimbra, Mondego River (Mondego basin) (9.1%) and in Tua River (Douro basin) (5.1%).

***Pseudostaurosira brevistriata* var. *capitata* (Héribaud) N.A. Andresen, Stoermer & Kreis** (Plate 38, Figs 1-35; Plate 39, Figs 1, 2) is a taxon that was only found in the site Monte dos Irmãos, Sôr Stream (Tejo basin) (15.1%). This taxon is based in *Fragilaria brevistriata* var. *capitata* Héribaud and later transferred to the genus *Peudostaurosira* by ANDRESEN, STOERMER & KREIS (2000).

***Rhoicosphenia adriatica* Caput Mihalić & Levkov** (Plate 74, Figs 1-27) was identified only in one site, Odemira (Mira River, Mira basin), where it was the dominant species (42.6%). This taxon was recently described from the Ombla River estuary (Croatia) by Caput Mihalić et Levkov in LEVKOV et al. (2010). Its distinctive characters are the denser striation and small valve size, furthermore, it was present in a station already near the estuary of Mira River, with a conductivity of 637 µS cm^{-1}.

***Tabellaria pseudoflocculosa* H. Kobayasi ex Mayama** (Plate 51, Figs 18-30; Plate 53, Figs 1-5; Plate 54, Figs 1-6) is a taxon that occurred in all seasons in the Meimoa Reservoir (Meimoa Stream, Tejo basin), being the dominant taxon in winter (57.2%). This is probably the first record of this taxon outside from Japan, from where it has recently been described by KOBAYASI et al. (2007).

There were several taxa (Table 3.4 and Table 3.3), which posed identification difficulties and were impossible to determine following the information provided in the literature available. These taxa are represented by cf. and aff. notations. When it was considered that the taxon was slightly different from a known species, which posed some doubts but even so it could be ascribed to that species, the notation cf. was used (e.g. *Encyonema* cf. *silesiacum*); and when the species was similar to a known species but it was still considered as a different taxon, the notation aff. was used (e.g. *Luticola* aff. *mutica*).

These taxa require deeper studies, which is already done for some of them, like *Achnanthidium pseudolineare* Van de Vijver, Novais & Ector (VAN DE VIJVER et al. 2011), *Achnanthidium caravelense* Novais & Ector (NOVAIS et al. 2010, presented in the chapter 4 of this work), and two new *Eunotia* species to be published in a volume about the genus *Eunotia* in the series Diatoms of Europe.

Nevertheless, there are other taxa, like *Pinnularia* sp., *Nupela* sp. and *Geissleria* sp. that are probably new to science but according to the International Code of Botanical Nomenclature should be formally described in journals of vast circulation and therefore formal proposals of nomenclatural changes and taxonomic novelties are not presented here.

3.3.2 Taxa distribution

The frequency of occurence of each taxon in the 14 main hydrographic basins has been determined in order to provide information about the distribution of the taxa identified. This information represents the percentage of sites in which the taxon was present within the basin, independently of its relative abundance. This information is provided only for the taxa identified with abundance above 1% in at least one sampling site, since the taxa with abundance below 1% are considered to be rare and their occurrence in one sampling site can be accidental.

Table 3.6 Frequency of occurrence of each taxon per main hydrographic basin (%). n represents the number of samples analysed per basin. Ribeiras do Algarve (n=28), Mira (n=11), Sado (n=25), Guadiana (n=28), Tejo (n=75), Ribeiras do Oeste (n=4), Mondego (n=35), Vouga (n=19), Douro (n=76), Leça (n=2), Ave (n=12), Cávado (n=18), Lima (n=12) and Minho (n=12).

Code	Taxon	Ribeiras do Algarve	Mira	Sado	Guadiana	Tejo	Ribeiras do Oeste	Mondego	Vouga	Douro	Leça	Ave	Cávado	Lima	Minho
AHMI	***Achnanthes helvetica* var. *minor*** Flower & Jones	0.00	0.00	0.00	0.00	0.00	0.00	2.86	21.05	2.63	0.00	0.00	0.00	16.67	0.00
ADAM	***Achnanthidium atomoides*** Monnier, Lange-Bertalot & Ector	0.00	0.00	0.00	0.00	0.00	0.00	5.71	5.26	6.58	0.00	0.00	0.00	0.00	0.00
ADCT	***Achnanthidium catenatum*** (Bílý & Marvan) Lange-Bertalot	7.14	27.27	8.00	7.14	12.00	0.00	17.14	10.53	7.89	0.00	0.00	5.56	8.33	0.00
	Achnanthidium* cf. *subatomus (Hustedt) Lange-Bertalot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.26	5.26	0.00	0.00	0.00	0.00	0.00
ADDA	***Achnanthidium daonense*** (Lange-Bertalot) Lange-Bertalot, Monnier & Ector	0.00	0.00	0.00	0.00	1.33	0.00	5.71	5.26	10.53	0.00	58.33	11.11	25.00	16.67
ADEU	***Achnanthidium eutrophilum*** (Lange-Bertalot) Lange-Bertalot	28.57	45.45	0.00	25.00	33.33	25.00	25.71	26.32	18.42	0.00	0.00	5.56	0.00	16.67
ADEG	***Achnanthidium exiguum*** (Grunow) Czarnecki sensu lato	0.00	0.00	0.00	3.57	26.67	0.00	8.57	0.00	3.95	0.00	8.33	0.00	0.00	0.00
ADGL	***Achnanthidium gracillimum*** (F. Meister) Lange-Bertalot	7.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.00	0.00	0.00	0.00
ACLI	***Achnanthidium lineare*** W. Smith	0.00	0.00	0.00	7.14	2.67	0.00	2.86	0.00	7.89	0.00	0.00	0.00	0.00	0.00
ACLI	***Achnanthidium lineare*** W. Smith abnormal form	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00
	Achnanthidium* aff. *lineare W. Smith	0.00	0.00	0.00	0.00	0.00	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Code	Taxon	Ribeiras do Algarve	Mira	Sado	Guadiana	Tejo	Ribeiras do Oeste	Mondego	Vouga	Douro	Leça	Ave	Cávado	Lima	Minho
ADMA	***Achnanthidium macrocephalum*** (Hustedt) Round & Bukhtiyarova	0.00	9.09	0.00	3.57	6.67	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ADMI	***Achnanthidium minutissimum*** (Kützing) Czarnecki	92.86	90.91	52.00	82.14	61.33	25.00	74.29	68.42	72.37	100.00	75.00	61.11	50.00	75.00
ADMT	***Achnanthidium minutissimum*** (Kützing) Czarnecki abnormal form	0.00	0.00	0.00	0.00	0.00	0.00	11.43	0.00	18.42	0.00	0.00	0.00	0.00	0.00
ADMI	***Achnanthidium minutissimum*** (Kützing) Czarnecki sensu lato	35.71	18.18	4.00	10.71	28.00	0.00	14.28	21.05	36.84	0.00	16.67	38.89	25.00	33.33
ADPY	***Achnanthidium pyrenaicum*** (Hustedt) Kobayasi	53.57	36.36	16.00	25.00	9.33	0.00	2.86	5.26	7.89	0.00	0.00	0.00	0.00	0.00
ADRI	***Achnanthidium rivulare*** Potapova & Ponader	0.00	0.00	0.00	0.00	5.33	0.00	20.00	0.00	22.37	0.00	8.33	0.00	0.00	8.33
ADRT	***Achnanthidium rivulare*** Potapova & Ponader abnormal form	0.00	0.00	0.00	0.00	0.00	0.00	2.86	5.26	15.79	0.00	0.00	0.00	0.00	0.00
ADSA	***Achnanthidium saprophilum*** (Kobayasi & Mayama) Round & Bukhtiyarova	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Achnanthidium* aff. *saprophilum (Kobayasi & Mayama) Round & Bukhtiyarova	0.00	9.09	0.00	3.57	5.33	0.00	0.00	10.53	0.00	0.00	0.00	5.56	0.00	0.00
	Achnanthidium pseudolineare Van de Vijver, Novais & Ector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.00	5.56	0.00	0.00
	Achnanthidium caravelense Novais & Ector	0.00	0.00	0.00	0.00	8.00	0.00	34.29	68.42	38.16	50.00	58.33	66.67	75.00	75.00
	***Achnanthidium* sp.3**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.67	0.00

Code	Taxon	Ribeiras do Algarve	Mira	Sado	Guadiana	Tejo	Ribeiras do Oeste	Mondego	Vouga	Douro	Leça	Ave	Cávado	Lima	Minho
	***Achnanthidium* sp.4**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.00	5.56	8.33	0.00
	***Achnanthidium* sp.5**	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	***Achnanthidium* sp.6**	0.00	0.00	0.00	0.00	2.67	0.00	14.29	0.00	15.79	0.00	25.00	16.67	8.33	16.67
	***Achnanthidium* sp.7**	0.00	0.00	0.00	0.00	1.33	0.00	5.71	0.00	9.21	0.00	0.00	11.11	8.33	8.33
	***Achnanthidium* sp.8**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.00	0.00	0.00	0.00
	***Achnanthidium* sp.9**	0.00	0.00	0.00	0.00	2.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ADSB	***Achnanthidium straubianum*** (Lange-Bertalot) Lange-Bertalot	14.29	0.00	4.00	3.57	5.33	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ADSO	***Achnanthidium subatomoides*** (Hustedt) Monnier, Lange-Bertalot & Ector	0.00	0.00	0.00	0.00	5.33	0.00	28.57	47.37	32.89	50.00	66.67	77.78	41.67	83.33
ADSH	***Achnanthidium subhudsonis*** (Hustedt) H. Kobayasi	3.57	0.00	0.00	25.00	36.00	25.00	57.14	52.63	65.79	0.00	16.67	33.33	16.67	50.00
ANMN	***Actinocyclus normanii*** (Gregory ex Greville) Hustedt	0.00	0.00	0.00	7.14	6.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ADMS	***Adlafia minuscula*** (Grunow) Lange-Bertalot	21.43	18.18	4.00	7.14	4.00	0.00	5.71	5.26	21.05	0.00	0.00	0.00	8.33	8.33
	***Adlafia* sp.1**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.21	0.00	0.00	0.00	0.00	0.00

Code	Taxon	Ribeiras do Algarve	Mira	Sado	Guadiana	Tejo	Ribeiras do Oeste	Mondego	Vouga	Douro	Leça	Ave	Cávado	Lima	Minho
	***Adlafia* sp.2**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.53	0.00	0.00	8.33	22.22	25.00	33.33
ACOP	***Amphora copulata*** (Kützing) Schoeman & Archibald	3.57	0.00	32.00	17.86	22.67	25.00	2.86	0.00	9.21	0.00	0.00	0.00	0.00	0.00
AMID	***Amphora indistincta*** Levkov	21.43	18.18	20.00	39.29	14.67	50.00	11.43	0.00	6.58	0.00	0.00	0.00	0.00	0.00
ALGT	***Amphora lange-bertalotii* var. *tenuis*** Levkov & Metzeltin	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AOVA	***Amphora ovalis*** (Kützing) Kützing	3.57	18.18	0.00	0.00	2.67	25.00	5.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
APED	***Amphora pediculus*** (Kützing) Grunow	57.14	54.55	80.00	75.00	65.33	50.00	31.43	0.00	30.26	0.00	0.00	0.00	0.00	8.33
AAMB	***Aulacoseira ambigua*** (Grunow) Simonsen	0.00	0.00	8.00	7.14	6.67	0.00	11.43	0.00	10.53	0.00	0.00	0.00	8.33	8.33
	Aulacoseira ambigua* f. *japonica (F. Meister) Tuji & D.M. Williams	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AUDI	***Aulacoseira distans*** (Ehrenberg) Simonsen	0.00	0.00	0.00	0.00	0.00	0.00	2.86	5.26	1.32	0.00	0.00	0.00	0.00	0.00
AUGR	***Aulacoseira granulata*** (Ehrenberg) Simonsen	0.00	0.00	12.00	10.71	6.67	0.00	11.43	0.00	9.21	0.00	0.00	0.00	0.00	8.33
AUGA	***Aulacoseira granulata* var. *angustissima*** (O. Müller) Simonsen	0.00	0.00	0.00	0.00	6.67	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00
AUPU	***Aulacoseira pusilla*** (F. Meister) Tuji & Houki	0.00	0.00	0.00	0.00	4.00	0.00	8.57	0.00	5.26	0.00	0.00	0.00	8.33	8.33

Code	Taxon	Ribeiras do Algarve	Mira	Sado	Guadiana	Tejo	Ribeiras do Oeste	Mondego	Vouga	Douro	Leça	Ave	Cávado	Lima	Minho
	Aulacoseira* cf. *subarctica (O. Müller) Haworth	0.00	0.00	0.00	0.00	6.67	0.00	0.00	0.00	1.32	0.00	0.00	0.00	0.00	8.33
AUTL	***Aulacoseira tenella*** (Nygaard) Simonsen	0.00	0.00	0.00	0.00	4.00	0.00	8.57	0.00	2.63	0.00	50.00	16.67	16.67	25.00
	***Aulacoseira* sp.**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33
BBRE	***Brachysira brebissonii* Ross**	7.14	18.18	0.00	0.00	0.00	0.00	2.86	5.26	5.26	0.00	8.33	38.89	41.67	8.33
BNEG	***Brachysira neglectissima*** Lange-Bertalot	3.57	0.00	0.00	0.00	0.00	0.00	2.86	5.26	1.32	0.00	16.67	27.78	25.00	0.00
	Caloneis* aff. *lancettula (Schulz) Lange-Bertalot & Witkowski	7.14	18.18	8.00	14.29	18.67	0.00	11.43	0.00	5.26	50.00	0.00	0.00	0.00	16.67
	Chamaepinnularia* cf. *rexii Veselá & Johansen	0.00	0.00	0.00	0.00	2.67	0.00	2.86	10.53	19.74	50.00	8.33	27.78	0.00	16.67
CNTH	***Cocconeis neothumensis*** Krammer	0.00	0.00	0.00	7.14	0.00	0.00	0.00	0.00	2.63	0.00	0.00	11.11	8.33	0.00
CPED	***Cocconeis pediculus*** Ehrenberg	14.29	18.18	16.00	17.86	14.67	0.00	14.29	0.00	7.89	0.00	0.00	0.00	0.00	0.00
CEUG	***Cocconeis euglypta*** Ehrenberg	39.29	63.64	76.00	71.43	52.00	75.00	17.14	5.26	46.05	0.00	8.33	0.00	8.33	8.33
CPEO	***Cocconeis placentula* var. *euglyptoides*** Geitler	3.57	0.00	0.00	0.00	6.67	25.00	8.57	0.00	6.58	0.00	0.00	0.00	0.00	0.00
CLNT	***Cocconeis lineata*** Ehrenberg	3.57	18.18	4.00	25.00	21.33	0.00	40.00	63.16	57.89	0.00	8.33	27.78	8.33	50.00

Code	Taxon	Ribeiras do Algarve	Mira	Sado	Guadiana	Tejo	Ribeiras do Oeste	Mondego	Vouga	Douro	Leça	Ave	Cávado	Lima	Minho
	Cocconeis lineata Ehrenberg abnormal form	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.58	0.00	0.00	0.00	0.00	0.00
CPPL	***Cocconeis placentula* var. *pseudolineata*** Geitler	21.43	45.45	48.00	25.00	36.00	0.00	22.86	15.79	39.47	0.00	0.00	5.56	0.00	33.33
	***Cocconeis* sp.**	3.57	45.45	4.00	50.00	22.67	0.00	14.29	5.26	30.26	0.00	8.33	22.22	8.33	16.67
CRCU	***Craticula cuspidata*** (Kützing) D.G. Mann	0.00	0.00	0.00	3.57	1.33	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00
CTPU	***Ctenophora pulchella*** (Ralfs ex Kützing) D.M. Williams & Round	0.00	0.00	0.00	3.57	2.67	0.00	8.57	0.00	2.63	0.00	8.33	16.67	33.33	16.67
CDUB	***Cyclostephanos dubius*** (Fricke) Round	0.00	0.00	8.00	10.71	2.67	0.00	0.00	0.00	3.95	0.00	0.00	0.00	0.00	8.33
CINV	***Cyclostephanos invisitatus*** (Hohn & Hellerman) Theriot, Stoermer & Håkansson	0.00	0.00	8.00	0.00	0.00	0.00	0.00	0.00	3.95	0.00	0.00	0.00	0.00	8.33
CATO	***Cyclotella atomus*** Hustedt	0.00	0.00	8.00	0.00	2.67	0.00	0.00	0.00	11.84	0.00	0.00	0.00	8.33	0.00
CMEN	***Cyclotella meneghiniana*** Kützing	7.14	9.09	48.00	35.71	29.33	25.00	5.71	5.26	15.79	50.00	0.00	5.56	0.00	16.67
COCE	***Cyclotella ocellata*** Pantocsek	0.00	0.00	0.00	0.00	2.67	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00
CAFF	***Cymbella affinis*** Kützing	28.57	18.18	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CAEX	***Cymbella excisa*** Kützing	10.71	0.00	0.00	3.57	1.33	0.00	5.71	0.00	2.63	0.00	0.00	0.00	0.00	0.00

Code	Taxon	Ribeiras do Algarve	Mira	Sado	Guadiana	Tejo	Ribeiras do Oeste	Mondego	Vouga	Douro	Leça	Ave	Cávado	Lima	Minho
CPPV	***Cymbella perparva*** Krammer	0.00	9.09	0.00	10.71	0.00	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00
CTUM	***Cymbella tumida*** (Brébisson) Van Heurck	0.00	9.09	0.00	3.57	14.67	0.00	20.00	0.00	9.21	0.00	8.33	0.00	8.33	16.67
CTGL	***Cymbella turgidula*** Grunow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.95	0.00	0.00	0.00	0.00	0.00
CBNA	***Cymbopleura naviculiformis*** (Auerswald) Krammer	0.00	0.00	0.00	0.00	1.33	0.00	0.00	5.26	1.32	0.00	0.00	0.00	0.00	0.00
DSUB	***Denticula subtilis*** Grunow	0.00	0.00	0.00	3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Diadesmis* cf. *biceps Arnott ex Grunow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.00
DCOF	***Diadesmis confervacea*** Kützing	0.00	0.00	0.00	0.00	5.33	0.00	0.00	0.00	0.00	0.00	8.33	5.56	0.00	8.33
DCOT	***Diadesmis contenta*** (Grunow ex Van Heurck) D.G. Mann	0.00	0.00	0.00	0.00	5.33	0.00	5.71	10.53	3.95	0.00	0.00	5.56	25.00	25.00
DPER	***Diadesmis perpusilla*** (Grunow) D.G. Mann sensu lato	0.00	0.00	0.00	0.00	0.00	0.00	22.86	26.32	2.63	0.00	0.00	0.00	0.00	0.00
DHIE	***Diatoma hyemalis*** (Roth) Heiberg	0.00	0.00	0.00	0.00	0.00	0.00	8.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMES	***Diatoma mesodon*** (Ehrenberg) Kützing	0.00	0.00	0.00	0.00	4.00	0.00	17.14	42.11	2.63	0.00	16.67	5.56	16.67	25.00
DELL	***Diploneis elliptica*** (Kützing) Cleve	0.00	9.09	4.00	0.00	4.00	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DSEP	***Diploneis separanda*** Lange-Bertalot	25.00	54.55	12.00	7.14	8.00	0.00	5.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Code	Taxon	Ribeiras do Algarve	Mira	Sado	Guadiana	Tejo	Ribeiras do Oeste	Mondego	Vouga	Douro	Leça	Ave	Cávado	Lima	Minho
DPST	***Discostella pseudostelligera*** (Hustedt) Houk & Klee	0.00	0.00	8.00	0.00	2.67	0.00	5.71	0.00	3.95	0.00	0.00	0.00	16.67	25.00
DSTE	***Discostella stelligera*** (Cleve & Grunow) Houk & Klee	0.00	9.09	0.00	0.00	9.33	0.00	11.43	0.00	3.95	0.00	41.67	22.22	16.67	33.33
ENLB	***Encyonema lange-bertalotii*** Krammer	7.14	0.00	4.00	14.29	9.33	0.00	0.00	0.00	5.26	0.00	0.00	0.00	0.00	0.00
	Encyonema* cf. *minutiforme Krammer	3.57	0.00	0.00	3.57	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENMI	***Encyonema minutum*** (Hilse in Rabenhorst) D.G. Mann	7.14	0.00	4.00	14.29	29.33	0.00	11.43	15.79	17.11	0.00	16.67	22.22	8.33	25.00
ENNG	***Encyonema neogracile*** Krammer	0.00	0.00	0.00	0.00	0.00	0.00	14.29	15.79	5.26	0.00	25.00	44.44	33.33	16.67
EPRO	***Encyonema prostratum*** (Berkeley) Kützing	0.00	0.00	4.00	3.57	5.33	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ELSE	***Encyonema silesiacum*** (Bleisch in Rabenhorst) D.G. Mann	0.00	18.18	4.00	32.14	13.33	0.00	5.71	15.79	7.89	0.00	0.00	11.11	25.00	16.67
	Encyonema* cf. *silesiacum (Bleisch in Rabenhorst) D.G. Mann	0.00	9.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENVE	***Encyonema ventricosum*** (C. Agardh) Grunow	32.14	18.18	12.00	21.43	26.67	25.00	31.43	21.05	23.68	0.00	8.33	22.22	0.00	25.00
	***Encyonema* sp.**	0.00	0.00	0.00	3.57	30.67	0.00	45.71	52.63	44.74	0.00	16.67	50.00	33.33	66.67
EAQL	***Encyonopsis aequalis*** (W. Smith) Krammer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.67	0.00
EOCO	***Eolimna comperei*** Ector, Coste & Iserentant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.26	0.00	0.00	0.00	0.00	0.00

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EOMI	***Eolimna minima*** (Grunow) Lange-Bertalot	35.71	63.64	80.00	71.43	78.67	25.00	71.43	73.68	80.26	100.00	100.00	61.11	41.67	75.00
EOMT	***Eolimna minima*** (Grunow) Lange-Bertalot abnormal form	0.00	0.00	0.00	0.00	0.00	0.00	2.86	0.00	13.16	0.00	0.00	0.00	0.00	0.00
ESBM	***Eolimna subminuscula*** (Manguin) Moser, Lange-Bertalot & Metzeltin	14.29	18.18	44.00	32.14	26.67	25.00	5.71	5.26	13.16	0.00	16.67	5.56	8.33	0.00
EOSP	***Eolimna* sp.**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.26	3.95	0.00	0.00	0.00	0.00	0.00
EADN	***Epithemia adnata*** (Kützing) Brébisson	0.00	0.00	4.00	0.00	9.33	0.00	0.00	0.00	9.21	0.00	0.00	0.00	0.00	0.00
ESOR	***Epithemia sorex*** Kützing	3.57	0.00	8.00	0.00	4.00	0.00	0.00	0.00	6.58	0.00	0.00	0.00	0.00	0.00
EEXI	***Eunotia exigua*** (Brébisson ex Kützing) Rabenhorst	0.00	0.00	0.00	0.00	0.00	0.00	5.71	10.53	1.32	0.00	16.67	5.56	33.33	16.67
EETE	***Eunotia exigua* var. *tenella*** (Grunow) Nörpel & Alles	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.26	2.63	0.00	16.67	0.00	0.00	8.33
EIMP	***Eunotia implicata*** Nörpel, Lange-Bertalot & Alles	7.14	27.27	0.00	0.00	5.33	0.00	11.43	15.79	5.26	0.00	25.00	27.78	33.33	25.00
EINC	***Eunotia incisa*** Gregory	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.53	5.26	0.00	16.67	11.11	8.33	8.33
EMIN	***Eunotia minor*** (Kützing) Grunow in Van Heurck	0.00	0.00	4.00	7.14	18.67	0.00	28.57	57.89	28.95	100.00	41.67	66.67	58.33	66.67
ESUB	***Eunotia subarcuatoides*** Alles, Nörpel & Lange-Bertalot	0.00	0.00	0.00	0.00	0.00	0.00	11.43	31.58	5.26	0.00	50.00	22.22	58.33	41.67
	***Eunotia* sp.1**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.00

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	***Eunotia* sp.2**	0.00	0.00	0.00	0.00	0.00	0.00	2.86	0.00	0.00	0.00	8.33	0.00	16.67	8.33
	***Eunotia* sp.4**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.00
	***Eunotia* sp.6**	0.00	0.00	0.00	0.00	0.00	0.00	2.86	0.00	1.32	0.00	8.33	0.00	0.00	8.33
ESOL	***Eunotia soleirolii*** (Kützing) Rabenhorst	17.86	0.00	8.00	3.57	5.33	0.00	0.00	0.00	1.32	50.00	0.00	5.56	0.00	0.00
	Eunotia* spp. aff. *exigua	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.00
	Fallacia* cf. *clepsidroides Witkowski	0.00	0.00	0.00	0.00	5.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FSAP	***Fistulifera saprophila*** (Lange-Bertalot & Bonik) Lange-Bertalot	14.29	0.00	28.00	25.00	10.67	0.00	14.29	5.26	6.58	0.00	8.33	5.56	8.33	8.33
FACD	***Fragilaria acidoclinata*** Lange-Bertalot & Hofmann	0.00	0.00	0.00	0.00	0.00	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FARC	***Fragilaria arcus*** (Ehrenberg) Cleve	0.00	0.00	0.00	0.00	0.00	0.00	8.57	10.53	1.32	0.00	0.00	5.56	0.00	0.00
FAUT	***Fragilaria austriaca*** (Grunow) Lange-Bertalot	3.57	0.00	0.00	0.00	1.33	25.00	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00
FCAN	***Fragilaria canariensis*** Lange-Bertalot	0.00	0.00	0.00	7.14	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FCAP	***Fragilaria capucina*** Desmazières	7.14	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FCRA	***Fragilaria capucina* var. *radians*** (Kützing) Lange-Bertalot	3.57	0.00	0.00	14.29	4.00	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00

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FCRO	***Fragilaria crotonensis*** Kitton	0.00	0.00	0.00	0.00	13.33	0.00	14.29	5.26	9.21	50.00	8.33	11.11	0.00	41.67
	Fragilaria* cf. *crotonensis Kitton	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FDEL	***Fragilaria delicatissima*** (W. Smith) Lange-Bertalot	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	3.95	0.00	0.00	5.56	0.00	0.00
FEXI	***Fragilaria exigua*** Grunow	0.00	0.00	0.00	0.00	6.67	0.00	5.71	0.00	10.53	0.00	0.00	0.00	0.00	8.33
FGRA	***Fragilaria gracilis*** Østrup	39.29	27.27	0.00	10.71	9.33	0.00	37.14	47.37	31.58	0.00	41.67	22.22	33.33	33.33
FGRT	***Fragilaria gracilis*** Østrup abnormal form	0.00	0.00	0.00	0.00	0.00	0.00	2.86	5.26	2.63	0.00	0.00	5.56	0.00	0.00
FNAN	***Fragilaria nanana*** Lange-Bertalot	3.57	0.00	0.00	3.57	1.33	0.00	0.00	0.00	1.32	0.00	0.00	5.56	0.00	0.00
FNIT	***Fragilaria nitzschioides*** Grunow in Van Heurck	3.57	0.00	0.00	0.00	1.33	25.00	8.57	10.53	7.89	0.00	25.00	0.00	8.33	8.33
	Fragilaria parva Tuji & D.M. Williams	0.00	0.00	0.00	0.00	5.33	0.00	8.57	5.26	22.37	0.00	0.00	27.78	0.00	25.00
FPEM	***Fragilaria perminuta*** (Grunow) Lange-Bertalot	3.57	0.00	0.00	0.00	22.67	25.00	48.57	68.42	17.11	0.00	66.67	33.34	33.33	58.33
FRUM	***Fragilaria rumpens*** (Kützing) G.W.F.Carlson	28.57	45.45	12.00	25.00	24.00	0.00	31.43	36.84	19.74	50.00	58.33	61.11	58.33	58.33
FSOC	***Fragilaria socia*** (J.H. Wallace) Lange-Bertalot	0.00	0.00	0.00	0.00	21.33	0.00	48.57	42.11	25.00	50.00	25.00	44.44	50.00	58.33
FVAU	***Fragilaria vaucheriae*** (Kützing) J.B. Petersen	14.29	54.55	48.00	50.00	14.67	0.00	0.00	0.00	7.89	0.00	0.00	0.00	0.00	0.00

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FVAU	***Fragilaria vaucheriae*** (Kützing) J.B. Petersen sensu lato	0.00	0.00	0.00	0.00	4.00	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FRAS	***Fragilaria* sp.**	46.43	27.27	12.00	3.57	0.00	0.00	0.00	5.26	10.53	0.00	0.00	5.56	8.33	8.33
GDEC	***Geissleria decussis*** (Østrup) Lange-Bertalot & Metzeltin	0.00	0.00	0.00	3.57	16.00	0.00	8.57	0.00	6.58	0.00	0.00	0.00	0.00	0.00
GESP	***Geissleria* sp.**	0.00	0.00	0.00	0.00	5.33	0.00	0.00	0.00	1.32	0.00	0.00	5.56	8.33	0.00
GADC	***Gomphonema acidoclinatum*** Lange-Bertalot & E. Reichardt	0.00	0.00	4.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	8.33	5.56	8.33	0.00
GANG	***Gomphonema angustatum*** (Kützing) Rabenhorst	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gomphonema* aff. *angustatum (Kützing) Rabenhorst	0.00	0.00	0.00	3.57	4.00	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00
GBOB	***Gomphonema bourbonense*** E. Reichardt	0.00	0.00	0.00	3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GCLA	***Gomphonema clavatum*** Ehrenberg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.00	0.00	0.00	0.00
	Gomphonema* cf. *commutatum Grunow	3.57	0.00	8.00	17.86	9.33	0.00	0.00	0.00	5.26	0.00	0.00	0.00	0.00	0.00
GEXL	***Gomphonema exilissimum*** (Grunow) Lange-Bertalot & E. Reichardt	3.57	0.00	0.00	3.57	13.33	0.00	8.57	21.05	3.95	0.00	33.33	27.78	25.00	16.67
	Gomphonema* cf. *gracile Ehrenberg	25.00	18.18	16.00	14.29	22.67	25.00	17.14	5.26	5.26	0.00	8.33	16.67	25.00	16.67
GIBE	***Gomphonema ibericum*** E. Reichardt	0.00	0.00	0.00	0.00	4.00	0.00	14.29	10.53	7.89	0.00	0.00	5.56	8.33	0.00

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GITA	***Gomphonema italicum*** Kützing	0.00	0.00	0.00	0.00	5.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GLGN	***Gomphonema lagenula*** Kützing	0.00	0.00	0.00	0.00	8.00	0.00	2.86	5.26	1.32	0.00	8.33	11.11	0.00	0.00
	Gomphonema lujanense E. Reichardt & N. Maidana	0.00	0.00	0.00	3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GMIN	***Gomphonema minutum*** (C. Agardh) C. Agardh	7.14	9.09	0.00	14.29	24.00	0.00	14.29	0.00	15.79	0.00	0.00	0.00	0.00	8.33
GOLI	***Gomphonema olivaceum*** (Hornemann) Brébisson	21.43	0.00	8.00	10.71	0.00	0.00	8.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GPAR	***Gomphonema parvulum*** (Kützing) Kützing	53.57	72.73	80.00	67.86	60.00	100.00	60.00	78.95	55.26	50.00	58.33	50.00	41.67	58.33
GPAS	***Gomphonema parvulum* var. *parvulum* f. *saprophilum*** Lange-Bertalot & E. Reichardt	3.57	0.00	0.00	0.00	13.33	25.00	8.57	0.00	0.00	0.00	8.33	0.00	8.33	0.00
GPUM	***Gomphonema pumilum*** (Grunow) E. Reichardt & Lange-Bertalot	14.29	0.00	0.00	21.43	6.67	25.00	11.43	5.26	18.42	0.00	0.00	0.00	0.00	0.00
GPEL	***Gomphonema pumilum* var. *elegans*** E. Reichardt & Lange-Bertalot	0.00	0.00	0.00	3.57	0.00	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GPRI	***Gomphonema pumilum* var. *rigidum*** E. Reichardt & Lange-Bertalot	46.43	63.64	40.00	32.14	21.33	50.00	14.29	5.26	25.00	0.00	0.00	0.00	0.00	8.33
	Gomphonema* cf. *pygmaeum Kociolek & Stoermer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00
GRHB	***Gomphonema rhombicum*** M. Schmidt	3.57	18.18	0.00	10.71	25.33	25.00	42.86	63.16	43.42	0.00	8.33	44.44	66.67	66.67

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GROS	***Gomphonema rosenstockianum*** Lange-Bertalot & E. Reichardt	89.29	90.91	40.00	46.43	18.67	0.00	17.14	0.00	5.26	0.00	0.00	0.00	0.00	0.00
GTRU	***Gomphonema truncatum*** Ehrenberg	3.57	18.18	4.00	17.86	5.33	0.00	5.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GAME	***Gomphonema uniserhombicum*** E. Reichardt	0.00	0.00	0.00	0.00	14.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOMS	***Gomphonema* sp.1**	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00
GOMS	***Gomphonema* sp.2**	0.00	0.00	0.00	7.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gomphosphenia* aff. *lingulatiformis (Lange-Bertalot & E. Reichardt) Lange-Bertalot	0.00	0.00	0.00	0.00	0.00	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOAH	***Gomphosphenia oahuensis*** (Hustedt) Lange-Bertalot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00
HLMO	***Halamphora montana*** **(**Krasske) Levkov	3.57	18.18	4.00	7.14	4.00	0.00	2.86	0.00	0.00	0.00	0.00	0.00	8.33	0.00
HVEN	***Halamphora veneta*** (Kützing) Levkov	14.29	18.18	28.00	64.29	13.33	0.00	0.00	5.26	1.32	0.00	0.00	0.00	0.00	0.00
HCAP	***Hippodonta capitata*** (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski	0.00	9.09	8.00	14.29	12.00	0.00	0.00	0.00	6.58	50.00	0.00	5.56	0.00	0.00
HHUN	***Hippodonta hungarica*** (Grunow) Lange-Bertalot, Metzeltin & Witkowski	7.14	0.00	20.00	10.71	8.00	50.00	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00
HPDA	***Hippodonta pseudoacceptata*** (H. Kobayasi) Lange-Bertalot	7.14	0.00	12.00	7.14	2.67	0.00	5.71	0.00	1.32	0.00	0.00	0.00	0.00	0.00

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KCLE	***Karayevia clevei*** (Grunow) Bukhtiyarova	14.29	9.09	4.00	21.43	20.00	25.00	2.86	0.00	17.11	0.00	0.00	0.00	0.00	0.00
KOBG	***Karayevia oblongella*** (Østrup) Aboal	60.71	63.64	8.00	17.86	25.33	50.00	37.14	63.16	21.05	50.00	33.33	44.44	41.67	58.33
KGES	***Kolbesia gessneri*** (Hustedt) Aboal	0.00	0.00	0.00	0.00	0.00	0.00	5.71	0.00	2.63	0.00	0.00	0.00	0.00	0.00
LHUN	***Lemnicola hungarica*** (Grunow) Round & Basson	0.00	0.00	4.00	3.57	8.00	0.00	2.86	0.00	3.95	0.00	0.00	5.56	0.00	0.00
LGOE	***Luticola goeppertiana*** (Bleisch in Rabenhorst) D.G. Mann	0.00	0.00	0.00	3.57	9.33	0.00	20.00	15.79	7.89	50.00	16.67	0.00	0.00	25.00
LMUT	***Luticola mutica*** (Kützing) D.G. Mann	0.00	0.00	4.00	7.14	2.67	0.00	0.00	5.26	3.95	0.00	8.33	0.00	0.00	0.00
	Luticola* aff. *mutica (Kützing) D.G. Mann	0.00	0.00	0.00	3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LVCF	***Luticola ventriconfusa*** Lange-Bertalot	0.00	9.09	0.00	3.57	2.67	0.00	2.86	0.00	3.95	0.00	0.00	0.00	0.00	0.00
MPMI	***Mayamaea permitis*** (Hustedt) Bruder & Medlin	17.86	9.09	44.00	35.71	12.00	25.00	11.43	26.32	27.63	0.00	16.67	0.00	8.33	8.33
MVAR	***Melosira varians*** C. Agardh	46.43	45.45	44.00	39.29	37.33	50.00	31.43	15.79	28.95	0.00	8.33	0.00	0.00	33.33
NAAN	***Navicula angusta*** Grunow	0.00	0.00	0.00	3.57	2.67	0.00	8.57	36.84	9.21	0.00	50.00	33.33	33.33	50.00
NANT	***Navicula antonii*** Lange-Bertalot	7.14	0.00	16.00	14.29	24.00	0.00	8.57	10.53	15.79	0.00	25.00	11.11	0.00	8.33
NCPR	***Navicula capitatoradiata*** Germain	0.00	0.00	12.00	17.86	6.67	0.00	5.71	0.00	14.47	0.00	0.00	5.56	0.00	8.33

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NCAR	***Navicula cari*** Ehrenberg	10.71	9.09	8.00	0.00	1.33	50.00	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00
NCTT	***Navicula cataracta-rheni*** Lange-Bertalot	0.00	0.00	0.00	0.00	2.67	0.00	14.29	0.00	22.37	0.00	0.00	0.00	0.00	0.00
NCRY	***Navicula cryptocephala*** Kützing	3.57	18.18	4.00	21.43	16.00	0.00	28.57	42.11	32.89	100.00	33.33	33.33	16.67	41.67
NCTE	***Navicula cryptotenella*** Lange-Bertalot	10.71	18.18	24.00	35.71	28.00	0.00	20.00	26.32	36.84	0.00	0.00	5.56	0.00	0.00
NCTO	***Navicula cryptotenelloides*** Lange-Bertalot	7.14	0.00	8.00	0.00	0.00	0.00	0.00	0.00	5.26	50.00	8.33	0.00	0.00	8.33
NEXI	***Navicula exilis*** Kützing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.00	0.00	0.00	8.33
NGER	***Navicula germainii*** J.H. Wallace	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00
NGRE	***Navicula gregaria*** Donkin	75.00	81.82	80.00	67.86	42.67	25.00	37.14	42.11	26.32	50.00	33.33	22.22	41.67	33.33
NLAN	***Navicula lanceolata*** (C. Agardh) Kützing	7.14	0.00	8.00	7.14	6.67	25.00	22.86	10.53	17.11	50.00	8.33	0.00	0.00	25.00
NNOT	***Navicula notha*** J.H. Wallace	0.00	0.00	0.00	0.00	24.00	0.00	22.86	21.05	25.00	0.00	50.00	55.56	33.33	41.67
NRAD	***Navicula radiosa*** Kützing	3.57	18.18	4.00	10.71	14.67	0.00	11.43	0.00	9.21	0.00	0.00	0.00	0.00	0.00
NRCH	***Navicula reichardtiana*** Lange-Bertalot	0.00	0.00	0.00	7.14	16.00	0.00	2.86	0.00	6.58	0.00	0.00	0.00	8.33	0.00
NRHY	***Navicula rhynchocephala*** Kützing	3.57	9.09	12.00	10.71	13.33	25.00	14.29	10.53	13.16	0.00	41.67	5.56	25.00	16.67

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NROS	***Navicula rostellata*** Kützing	0.00	0.00	4.00	0.00	21.33	0.00	2.86	0.00	18.42	50.00	0.00	0.00	0.00	0.00
	Navicula schmassmannii Hustedt	0.00	0.00	0.00	0.00	0.00	0.00	2.86	0.00	1.32	0.00	0.00	5.56	0.00	0.00
NSHR	***Navicula schroeteri*** F. Meister	3.57	0.00	4.00	10.71	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NSIA	***Navicula simulata*** Manguin	0.00	36.36	28.00	3.57	2.67	0.00	2.86	0.00	2.63	0.00	0.00	0.00	0.00	0.00
NTPT	***Navicula tripunctata*** (O.F. Müller) Bory	17.86	9.09	24.00	21.43	21.33	75.00	14.29	5.26	10.53	0.00	0.00	0.00	0.00	0.00
NTRV	***Navicula trivialis*** Lange-Bertalot	0.00	0.00	0.00	10.71	6.67	0.00	0.00	0.00	1.32	0.00	0.00	0.00	0.00	0.00
NVEN	***Navicula veneta*** Kützing	53.57	81.82	88.00	78.57	54.67	50.00	14.29	26.32	13.16	0.00	33.33	22.22	8.33	16.67
NACD	***Nitzschia acidoclinata*** Lange-Bertalot	3.57	27.27	0.00	7.14	18.67	0.00	20.00	21.05	25.00	50.00	8.33	22.22	8.33	33.33
NAGI	***Nitzschia agnita*** Hustedt	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	6.58	0.00	0.00	5.56	0.00	0.00
NAMP	***Nitzschia amphibia*** Grunow	10.71	18.18	56.00	39.29	45.33	25.00	17.14	10.53	22.37	50.00	16.67	0.00	0.00	8.33
NIAR	***Nitzschia archibaldii*** Lange-Bertalot	3.57	0.00	4.00	0.00	1.33	0.00	0.00	0.00	1.32	0.00	0.00	0.00	0.00	0.00
NBRE	***Nitzschia brevissima*** Grunow	0.00	9.09	0.00	3.57	8.00	0.00	0.00	0.00	0.00	0.00	8.33	5.56	0.00	8.33
NCPL	***Nitzschia capitellata*** Hustedt	3.57	0.00	24.00	7.14	8.00	25.00	2.86	5.26	1.32	0.00	8.33	11.11	0.00	8.33

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NCLA	***Nitzschia clausii*** Hantzsch	3.57	27.27	4.00	3.57	2.67	0.00	0.00	0.00	0.00	0.00	8.33	11.11	8.33	0.00
NDIS	***Nitzschia dissipata*** (Kützing) Grunow	17.86	9.09	16.00	32.14	13.33	25.00	31.43	26.32	15.79	0.00	33.33	5.56	8.33	33.33
NDIV	***Nitzschia diversa*** Hustedt	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NFIL	***Nitzschia filiformis*** (W. Smith) Van Heurck	0.00	0.00	0.00	0.00	5.33	0.00	11.43	5.26	1.32	0.00	8.33	5.56	8.33	8.33
NFON	***Nitzschia fonticola*** Grunow	0.00	9.09	16.00	32.14	29.33	0.00	22.86	0.00	26.32	0.00	8.33	5.56	0.00	16.67
NIFR	***Nitzschia frustulum*** (Kützing) Grunow	3.57	0.00	16.00	21.43	10.67	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00
NHAN	***Nitzschia hantzschiana*** Rabenhorst	0.00	0.00	0.00	0.00	2.67	0.00	8.57	5.26	7.89	50.00	8.33	5.56	0.00	0.00
	Nitzschia* cf. *incognita Legler & Krasske	3.57	0.00	0.00	3.57	1.33	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NINC	***Nitzschia inconspicua*** Grunow	67.86	90.91	76.00	78.57	53.33	50.00	22.86	21.05	26.32	50.00	16.67	16.67	25.00	16.67
NMIC	***Nitzschia microcephala*** Grunow	28.57	18.18	12.00	39.29	12.00	0.00	2.86	0.00	1.32	0.00	0.00	5.56	0.00	0.00
NPAL	***Nitzschia palea*** (Kützing) W. Smith	32.14	45.45	24.00	25.00	21.33	50.00	20.00	42.11	15.79	100.00	66.67	22.22	16.67	25.00
NPAE	***Nitzschia paleacea*** (Grunow) Grunow	25.00	27.27	40.00	32.14	24.00	0.00	11.43	10.53	9.21	0.00	8.33	16.67	0.00	16.67

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NIPF	***Nitzschia paleaeformis*** Hustedt	0.00	0.00	0.00	3.57	1.33	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00
NIPM	***Nitzschia perminuta*** (Grunow) M. Peragallo	7.14	0.00	20.00	3.57	8.00	0.00	8.57	10.53	9.21	0.00	33.33	5.56	16.67	25.00
	Nitzschia* cf. *rectiformis Hustedt	0.00	0.00	0.00	0.00	0.00	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NZSU	***Nitzschia supralitorea*** Lange-Bertalot	17.86	27.27	52.00	39.29	24.00	0.00	2.86	0.00	11.84	50.00	0.00	0.00	8.33	8.33
NTUB	***Nitzschia tubicola*** Grunow	0.00	0.00	0.00	3.57	0.00	0.00	2.86	0.00	0.00	0.00	0.00	5.56	0.00	0.00
NIVA	***Nitzschia valdestriata*** Aleem & Hustedt	7.14	27.27	4.00	0.00	8.00	0.00	5.71	0.00	1.32	0.00	0.00	5.56	8.33	8.33
NVSA	***Nitzschia vitrea* var. *salinarum*** Grunow	0.00	0.00	0.00	3.57	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	***Nitzschia* sp1.**	0.00	0.00	0.00	0.00	5.33	0.00	2.86	0.00	9.21	0.00	0.00	0.00	0.00	16.67
	***Nitzschia* sp.2**	0.00	0.00	4.00	0.00	5.33	0.00	0.00	0.00	2.63	0.00	0.00	0.00	8.33	0.00
	***Nitzschia* sp.3**	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NUIP	***Nupela imperfecta*** (Schimanski) Lange-Bertalot	0.00	0.00	0.00	0.00	0.00	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NULA	***Nupela lapidosa*** (Krasske) Lange-Bertalot	0.00	0.00	0.00	0.00	1.33	0.00	5.71	5.26	1.32	0.00	0.00	5.56	8.33	0.00
NUPS	***Nupela* sp.**	0.00	0.00	0.00	0.00	0.00	0.00	5.71	21.05	2.63	50.00	16.67	16.67	8.33	0.00

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PFIB	***Peronia fibula*** (Brébisson ex Kützing) Ross	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.00	11.11	25.00	16.67
PBRE	***Pinnularia brebissonii*** (Kützing) Rabenhorst	3.57	0.00	0.00	0.00	2.67	25.00	0.00	0.00	1.32	0.00	0.00	0.00	0.00	0.00
	Pinnularia* cf. *krammeri Metzeltin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.53	0.00	0.00	0.00	0.00	0.00	0.00
	Pinnularia* cf. *obscura Krasske	0.00	0.00	4.00	3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PMIC	***Pinnularia microstauron*** (Ehrenberg) Cleve	0.00	0.00	0.00	3.57	5.33	0.00	2.86	0.00	1.32	0.00	0.00	0.00	0.00	8.33
PSBV	***Pinnularia subbrevistriata*** Krammer	3.57	0.00	0.00	0.00	0.00	25.00	2.86	5.26	0.00	50.00	8.33	0.00	0.00	0.00
PSCA	***Pinnularia subcapitata*** Gregory	0.00	0.00	0.00	0.00	1.33	0.00	20.00	31.58	14.47	0.00	8.33	0.00	16.67	8.33
PINS	***Pinnularia* sp.**	3.57	9.09	0.00	0.00	1.33	25.00	0.00	0.00	0.00	0.00	25.00	0.00	0.00	16.67
PDAU	***Planothidium daui*** (Foged) Lange-Bertalot	0.00	0.00	0.00	0.00	0.00	0.00	5.71	0.00	0.00	0.00	0.00	16.67	8.33	0.00
PTDE	***Planothidium delicatulum*** (Kützing) Round & Bukhtiyarova sensu lato	0.00	0.00	0.00	0.00	16.00	0.00	2.86	0.00	2.63	0.00	8.33	5.56	0.00	0.00
PLEN	***Planothidium engelbrechtii*** (Cholnoky) Round & Bukhtiyarova	7.14	0.00	28.00	17.86	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PLFR	***Planothidium frequentissimum*** (Lange-Bertalot) Lange-Bertalot	82.14	72.73	92.00	82.14	86.67	75.00	62.86	47.37	61.84	50.00	25.00	38.89	16.67	25.00

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PGRN	***Planothidium granum*** (Hohn & Hellerman) Lange-Bertalot	0.00	0.00	0.00	0.00	8.00	0.00	5.71	15.79	9.21	0.00	16.67	27.78	16.67	8.33
PHAY	***Planothidium haynaldii*** (Schaarschmidt) Lange-Bertalot	0.00	0.00	0.00	0.00	2.67	0.00	0.00	0.00	6.58	0.00	0.00	0.00	0.00	0.00
PTLA	***Planothidium lanceolatum*** (Brébisson ex Kützing) Lange-Bertalot	28.57	72.73	48.00	28.57	38.67	25.00	48.57	36.84	53.95	50.00	33.33	33.33	0.00	33.33
PLMN	***Planothidium minutissimum*** (Krasske) Lange-Bertalot	0.00	0.00	0.00	3.57	0.00	0.00	0.00	0.00	0.00	0.00	16.67	0.00	8.33	25.00
PRST	***Planothidium rostratum*** (Østrup) Lange-Bertalot	0.00	0.00	4.00	0.00	13.33	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	8.33
PLEV	***Pleurosira laevis*** (Ehrenberg) Compère	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PMRG	***Psammothidium marginulatum*** (Grunow) Bukhtiyarova & Round	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.00	5.56	8.33	0.00
	Psammothidium* cf. *rechtensis (Leclercq) Lange-Bertalot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.00	0.00	0.00	0.00
PSSB	***Pseudostaurosira alvareziae*** Cejudo-Figueiras, E. Morales & Ector	0.00	9.09	0.00	25.00	36.00	0.00	0.00	10.53	7.89	0.00	8.33	33.33	8.33	0.00
PBCA	***Pseudostaurosira brevistriata* v. *capitata*** (Héribaud) N.A. Andresen, Stoermer & Kreis	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PSSE	***Pseudostaurosira elliptica*** (Schumann) Edlund, E. Morales & Spaulding	0.00	9.09	0.00	21.43	18.67	0.00	0.00	0.00	5.26	0.00	0.00	0.00	0.00	0.00
	Pseudostaurosira* aff. *polonica (Witak & Lange-Bertalot) Morales & Edlund	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.00	0.00	0.00	0.00

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	***Punctastriata* sp.**	0.00	0.00	0.00	3.57	0.00	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00
RSIN	***Reimeria sinuata*** (Gregory) Kociolek & Stoermer	75.00	81.82	32.00	42.86	36.00	50.00	68.57	21.05	55.26	0.00	8.33	11.11	8.33	25.00
RUNI	***Reimeria uniseriata*** Sala, Guerrero & Ferrario	32.14	27.27	40.00	17.86	16.00	25.00	11.43	0.00	6.58	0.00	0.00	0.00	0.00	0.00
RABB	***Rhoicosphenia abbreviata*** (C. Agardh) Lange-Bertalot	10.71	27.27	40.00	28.57	32.00	0.00	11.43	0.00	22.37	0.00	0.00	5.56	0.00	8.33
	Rhoicosphenia adriatica Caput Mihalić & Levkov	0.00	9.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RGIB	***Rhopalodia gibba*** (Ehrenberg) O. Müller	0.00	9.09	8.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEBA	***Sellaphora bacillum*** (Ehrenberg) D.G. Mann	0.00	0.00	0.00	3.57	0.00	0.00	0.00	0.00	7.89	0.00	0.00	0.00	0.00	0.00
SPUP	***Sellaphora pupula*** (Kützing) Mereschkowksy	3.57	9.09	20.00	14.29	16.00	25.00	2.86	31.58	7.89	50.00	25.00	11.11	8.33	0.00
SSEM	***Sellaphora seminulum*** (Grunow) D.G. Mann	25.00	36.36	56.00	32.14	41.33	25.00	20.00	5.26	30.26	50.00	50.00	38.89	16.67	25.00
SCBI	***Staurosira construens* var. *binodis*** (Ehrenberg) Hamilton	0.00	0.00	0.00	3.57	14.67	0.00	0.00	0.00	15.79	0.00	0.00	0.00	0.00	0.00
SSVE	***Staurosira venter*** (Ehrenberg) Cleve & Möller	0.00	9.09	12.00	42.86	48.00	0.00	28.57	10.53	28.95	50.00	16.67	33.33	0.00	8.33
	***Staurosira* sp.**	0.00	0.00	0.00	14.29	2.67	0.00	2.86	0.00	6.58	0.00	0.00	5.56	0.00	0.00
SPIN	***Staurosirella pinnata*** (Ehrenberg) D.M. Williams & Round	3.57	9.09	0.00	17.86	16.00	25.00	0.00	0.00	15.79	0.00	0.00	0.00	0.00	8.33

Code	Taxon	Ribeiras do Algarve	Mira	Sado	Guadiana	Tejo	Ribeiras do Oeste	Mondego	Vouga	Douro	Leça	Ave	Cávado	Lima	Minho
SHAN	***Stephanodiscus hantzschii*** Grunow	0.00	0.00	0.00	7.14	1.33	0.00	0.00	0.00	5.26	0.00	0.00	0.00	0.00	16.67
STIN	***Stephanodiscus invisitatus*** Hohn & Hellermann	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SNEO	***Stephanodiscus neoastraea*** Håkansson & Hickel	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00
SRBA	***Surirella roba*** Leclercq	0.00	0.00	0.00	0.00	2.67	0.00	8.57	15.79	6.58	0.00	25.00	16.67	33.33	0.00
TFLO	***Tabellaria flocculosa*** (Roth) Kützing	0.00	0.00	0.00	0.00	1.33	0.00	5.71	0.00	1.32	0.00	25.00	27.78	8.33	8.33
TDEB	***Tryblionella debilis*** Arnott ex O'Meara	0.00	9.09	4.00	3.57	0.00	0.00	0.00	0.00	0.00	50.00	0.00	0.00	8.33	0.00
THUN	***Tryblionella hungarica*** (Grunow) D.G. Mann	3.57	9.09	28.00	32.14	13.33	25.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UBIC	***Ulnaria biceps*** (Kützing) Compère	32.14	27.27	12.00	10.71	16.00	25.00	17.14	5.26	5.26	0.00	8.33	0.00	0.00	0.00
UDEA	***Ulnaria delicatissima* var. *angustissima*** (Grunow) Aboal & P.C. Silva	7.14	9.09	0.00	14.29	2.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UULN	***Ulnaria ulna*** (Nitzsch) Compère	35.71	9.09	8.00	21.43	17.33	0.00	34.29	15.79	14.47	0.00	25.00	16.67	8.33	16.67

To facilitate the comprehension of the Table 3.6, with the frequency of occurrence of all taxa, in Table 3.7 are summarized the most frequent taxa per basin. As most frequent were considered those taxa which occurred in more of 50% of the sites of each basin.

From the analysis of Table 3.7 can be observed that the most widespread taxa in each basin are generally similar, only changing their frequencies. Therefore, the most widespread taxa throughout the country are: *Achnanthidium minutissimum*, *Planothidium frequentissimum*, *Eolimna minima* and *Gomphonema parvulum*. It is interesting to notice that *Gomphonema rosenstockianum* is frequent in the Ribeiras do Algarve and Mira but is absent from the other basins, which is probably due to geological differences. In the Northern basins *Achnanthidium subatomoides*, *Achnanthidium caravelense* and *Eunotia* spp. are among the most frequent taxa, while they are absent from the Southern and Centre basins.

Achnanthidium minutissimum was also reported as the most frequent taxon for the Spanish part of the Douro basin by BLANCO et al. (2010) and for the natural lakes in Azores by GONÇALVES (2008). This wide distribution may be explained by its high ecological amplitude (V=1) as seen in the OMNIDIA v. 5.3. The group of species around *Achnanthidium minutissimum* (KÜTZING) CZARNECKI is one of the most complex groups of non-marine diatoms and its taxonomy has been the subject of intensive debate (VAN DE VIJVER et al. 2011). This taxon is usually considered ubiquitous and cosmopolitan (VAN DAM et al. 1994) and taxa (including species, varieties and forms) belonging to this group often dominate the diatom flora in freshwater systems in Europe and beyond (KRAMMER & LANGE-BERTALOT 1991b; VAN DAM et al. 1994; PRYGIEL & COSTE 1999; POTAPOVA & CHARLES 2007; MARTÍN et al. 2010).

Table 3.7 Most frequent taxa in each basin (frequency of occurrence above 50% of the sites per basin). n represents the number of samples analysed per basin. Ribeiras do Algarve (n=28), Mira (n=11), Sado (n=25), Guadiana (n=28), Tejo (n=75), Ribeiras do Oeste (n=4), Mondego (n=35), Vouga (n=19), Douro (n=76), Leça (n=2), Ave (n=12), Cávado (n=18), Lima (n=12) and Minho (n=12).

Ribeiras do Algarve		**Mira**		**Sado**		**Guadiana**		**Tejo**	
Taxon	**%**	**Taxon**	**%**	**Taxon**	**%**	**Taxon**	**%**	**Taxon**	**%**
A. minutissimum	92.86	*A. minutissimum*	90.91	*P. frequentissimum*	92.00	*P. frequentissimum*	82.14	*P. frequentissimum*	86.67
G. rosenstockianum	89.29	*G. rosenstockianum*	90.91	*N. veneta*	88.00	*A. minutissimum*	82.14	*E. minima*	78.67
P. frequentissimum	82.14	*N. inconspicua*	90.91	*N. gregaria*	80.00	*N. veneta*	78.57	*A. pediculus*	65.33
N. gregaria	75.00	*N. gregaria*	81.82	*G. parvulum*	80.00	*N. inconspicua*	78.57	*A. minutissimum*	61.33
R. sinuata	75.00	*R. sinuata*	81.82	*E. minima*	80.00	*A. pediculus*	75.00	*G. parvulum*	60.00
N. inconspicua	67.86	*N. veneta*	81.82	*A. pediculus*	80.00	*E. minima*	71.43	*N. veneta*	54.67
K. oblongella	60.71	*P. frequentissimum*	72.73	*N. inconspicua*	76.00	*C. euglypta*	71.43	*N. inconspicua*	53.33
A. pediculus	57.14	*G. parvulum*	72.73	*C. euglypta*	76.00	*N. gregaria*	67.86	*C. euglypta*	52.00
N. veneta	53.57	*P. lanceolatum*	72.73	*S. seminulum*	56.00	*G. parvulum*	67.86		
G. parvulum	53.57	*K. oblongella*	63.64	*N. amphibia*	56.00	*H. veneta*	64.29		
A. pyrenaicum	53.57	*G. pumilum* var. *rigidum*	63.64	*A. minutissimum*	52.00				
		C. placentula var. *euglypta*	63.64	*N. supralitorea*	52.00				
		E. minima	63.64						
		A. pediculus	54.55						
		D. separanda	54.55						
		F. vaucheriae	54.55						

Ribeiras do Oeste		Mondego		Vouga		Douro		Leça	
Taxon	**%**	**Taxon**	**%**	**Taxon**	**%**	**Taxon**	**%**	**Taxon**	**%**
G. parvulum	100.00	*A. minutissimum*	74.29	*G. parvulum*	78.95	*E. minima*	80.26	*A. minutissimum*	100.00
P. frequentissimum	75.00	*E. minima*	71.43	*E. minima*	73.68	*A. minutissimum*	72.37	*E. minima*	100.00
C. euglypta	75.00	*R. sinuata*	68.57	*A. minutissimum*	68.42	*A. subhudsonis*	65.79	*E. minor*	100.00
N. tripunctata	75.00	*P. frequentissimum*	62.86	*A. caravelense*	68.42	*P. frequentissimum*	61.84	*N. cryptocephala*	100.00
		G. parvulum	60.00	*K. oblongella*	63.16	*C. lineata*	57.89	*N. palea*	100.00
		A. subhudsonis	57.14	*G. rhombicum*	63.16	*G. parvulum*	55.26		
				F. perminuta	63.16	*R. sinuata*	55.26		
				C. lineata	63.16	*P. lanceolatum*	53.95		
				E. minor	57.89				
				A. subhudsonis	52.63				
				Encyonema sp.	52.63				

Ave		Cávado		Lima		Minho	
Taxon	**%**	**Taxon**	**%**	**Taxon**	**%**	**Taxon**	**%**
E. minima	100.00	*A. subatomoides*	77.78	*A. caravelense*	75.00	*A. subatomoides*	83.33
A. minutissimum	75.00	*A. caravelense*	66.67	*G. rhombicum*	66.67	*A. caravelense*	75.00
N. palea	66.67	*E. minor*	66.67	*E. minor*	58.33	*E. minima*	75.00
A. subatomoides	66.67	*E. minima*	61.11	*E. subarcuatoides*	58.33	*A. minutissimum*	75.00
F. perminuta	66.67	*A. minutissimum*	61.11	*F. rumpens*	58.33	*E. minor*	66.67
A. caravelense	58.33	*F. rumpens*	61.11			*Encyonema* sp.	66.67
F. rumpens	58.33	*N. notha*	55.56			*G. rhombicum*	66.67
G. parvulum	58.33					*F. rumpens*	58.33
A. daonense	58.33					*G. parvulum*	58.33
						K. oblongella	58.33
						F. socia	58.33
						F. perminuta	58.33

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Chapter 4

TAXONOMIC STUDIES OF COMMON DIATOM SPECIES COMPLEXES IN PORTUGAL

4 Taxonomic studies of common diatom species complexes in Portugal

4.1 Introduction

The perception of diversity, the detection of biogeographical patterns and the assessment of rarity are inextrincably linked with taxonomy (MANN & DROOP 1996). The diatom taxonomy is highly influenced by the species concept adopted, a wider species concept will group taxa similar while a narrower species concept will split taxa based in small differences. These different approaches lead to a more or less fine grained taxonomy with consequent increase in the number of taxa.

During the last decades, took place a rapid and vast proliferation of new diatom taxa. According to LANGE-BERTALOT (1990), there are several causes for this increase in the taxa number, e.g. new taxa have proved to be synonyms of older ones, since authors weren't aware of the existence of the latter; the known "image" of similar older taxa is often not related to the type material; the diagnosis and illustrations of new taxa often do not include the real complete spectrum of variation of the taxon, omitting for instance other forms of the life-cycle; the drawings provided for older taxa are often not enough precise to allow the recognition of the intended taxon. There is therefore a need to find a compromise between the taxonomist and the practical use of diatom taxa in other disciplines, such as hydrology, geology and ecology. LANGE-BERTALOT (1990) suggests that the taxonomist should describe as new what is apparently different and synonymise what seems to be identical. Nevertheless, whole of his decisions have to be clearly justified and follow the scientific theory, according to which his hypothesis have to be formulated in such a way that they can be disproved by new findings, and if so, be replaced by new hypothesis.

The use of the scanning electron microscopy revolutionized diatom systematics, revealling important taxonomical ultrastructures that were not discernible under light microscope and being nowadays an essential tool for taxon delimitation (ALVERSON 2008). Also the morphometric analysis, based in the extraction of outline shape features, combined with multivariate analysis methods (e.g. principal component analysis – PCA) has proved to be a useful tool to detect and quantify subtle morphological variation and therefore to help to solve taxonomical difficulties (MANN et al. 2004; POTAPOVA & HAMILTON 2007; VESELÁ et al. 2009).

Most recently, the application of molecular biological techniques to systematic studies of diatoms has revealed more variation and plays nowadays an important role in the discovery and delimitation of new species (ALVERSON 2008), e.g. the *Navicula cryptocephala* KÜTZING and morphologically similar taxa (POULÍČKOVÁ et al. 2010); the *Sellaphora pupula* species complex (MANN et al. 2004) and the *Cyclotella meneghiniana* complex (BESZTERI et al. 2005). These studies, together with recent taxonomic research on diatoms suggests that traditional species boundaries, largely based on variation of the frustule have been drawn too widely and real species diversity has probably been greatly underestimated (MANN 1999; EVANS et al. 2009).

As the freshwater diatom flora of the entire territory of Portugal has never been a subject of deep studies, there are species complexes that pose identification problems, due to similarities under light microscope or to a lack of information about their morphology, ultrastructure or ecology. Therefore, the objective of this part of the work is to clarify some of these doubts and increase the knowledge about these species, through a deep analysis based on light and scanning electron microscopy complemented with information about their ecological preferences and geographical distribution.

One of these cases is the *Gomphonema tergestinum* (GRUNOW) M. SCHMIDT and *G. rosenstockianum* LANGE-BERTALOT & E. REICHARDT complex, since this species complex is quite frequent and abundant in the South of Portugal. These species can be easily misidentified at first sight, especially in the light microscopy due to morphological similarities. Therefore, it is important to provide detailed characterization under light and scanning electron microscopy to allow its correct identification, as well as further information about their ecological preferences and geographical distribution. In order to fulfill these objectives, the recommendations made by LANGE-BERTALOT (1990) and previously referred, were followed. A comparison with the type material of *G. rosenstockianum* is performed (since the type material of *G. tergestinum* was not found), a complete series of light micrographs is provided to show the complete morphological variability of both species, several populations from distinct geographic areas are compared and illustrated, additionally scanning electron micrographs are provided to illustrate ultrastructural features that can allow their identification, and moreover a geometric morphometric analysis combined with principal component analysis is applied to quantify the morphological variation.

Another problematic important group is the *Achnanthidium minutissimum* species complex, due to several reasons, such as the small size of the majority of the specimens, the lack of enough diagnostic characters in light and scanning electron microscopy, the reduced number of detailed studies of type material and the great morphological variability within the populations, as pointed out by MORALES et al. (2011). During the course of this study, several *Achnanthidium* taxa have been identified in Portugal, some of which could not be ascribed to any of the already described species. They were kept separately under a provisional name, following the recommendations of PONADER & POTAPOVA (2007) who state that it may not be as important to attach a name to a population as to keep it separate, even if minor morphological differences are detected, since these variations might express a particular set of environmental conditions that are important to consider in order to improve the accuracy of environmental assessment. During this study one of these taxa is formerly described by means of light and scanning electron microscopy. It was clear that this was a taxon worth to be formally described, since there was a constancy of its morphological characters among the totality of the populations studied and it presented clear different ecological preferences from the most similar *Achnanthidium* species. Furthermore, the correct identification of this species can be valuable in the framework of the application of diatom indices for the ecological quality evaluation, since its ecological preferences are completely different from the closest morphological species *Achnanthidium eutrophilum* (LANGE-BERTALOT) LANGE-BERTALOT. Once more the recommendations of LANGE-BERTALOT (1990) have been followed, in order to propose this as a new species, a complete series of light microscope micrographs and several scanning electron microscope micrographs are provided, a

comparison with the illustrations of the type material of the morphologically most similar species is performed, a morphometric comparison between both species is performed and statistically proved and in addition a comparison of the ecological preferences of both species for several environmental parameters is performed and statistically proved.

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4.2 Morphological examination and biogeography of the *Gomphonema rosenstockianum* and *G. tergestinum* species complex (Bacillariophyceae)

Abstract

The type material of *Gomphonema rosenstockianum* Lange-Bert. & E. Reichardt from La Gomera (Canary Islands, Spain) and epilithic material of rivers from several European countries were examined using light and scanning electron microscopy in order to improve the knowledge on the taxonomical status of the *G. rosenstockianum* and *G. tergestinum* (Grunow) M. Schmidt species complex. Two other *Gomphonema* species, *G. supertergestinum* E. Reichardt and *G. angustius* E. Reichardt, recently described and belonging to the same group, are also presented in detail. After the analysis of several populations of *G. rosenstockianum* and *G. tergestinum* it was possible to define several reliable criteria to allow morphological differentiation of both species under LM and SEM as well. A geometric morphometric analysis clearly demonstrated the separation of these taxa considering valve outline, size and shape of the central area and position of the stigma. Apart from the morphological analysis, compilation of the results of this study has also revealed differences in ecological preferences of the two species. World and European distribution maps of the four *Gomphonema* taxa are presented.

Key words: diatoms, geometric morphometry, *Gomphonema*, morphology, type material, ultrastructure

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4.2.1 Introduction

The biraphidaceous, heteropolar diatom genus *Gomphonema* was erected by EHRENBERG in 1832, and is very common in freshwater haptobenthic communities (ROUND et al. 1990). Within this genus, the taxonomy of *Gomphonema tergestinum* (Grunow) M. Schmidt and *G. rosenstockianum* Lange-Bert. & E. Reichardt is considered problematic to the point that these two species are commonly misidentified at first sight, especially under light microscopy (LM).

Gomphonema rosenstockianum was described and illustrated by light and scanning electron microscopy (SEM) in 1993 by LANGE-BERTALOT & REICHARDT from La Gomera, Canary Islands, Spain (LANGE-BERTALOT 1993). Its occurrence, according to LANGE-BERTALOT (1993), is limited to several slightly alkaline waters from Canary Islands (La Gomera and Tenerife) with moderate conductivity and oligosaprobic to β-mesosaprobic waters.

Gomphonema tergestinum was originally described from Trieste (Italy) by GRUNOW as *Gomphonema semiapertum* var. *tergestina* GRUNOW in VAN HEURCK 1880. Afterwards, M. SCHMIDT drew 8 figures of *G. tergestinum* Grunow in SCHMIDT et al. (1902), based on the analysis of samples collected in Cresswell (United Kingdom) and in Gülzow, Mecklenburg-Vorpommern (North of Germany). These initial mentions of the taxon (GRUNOW's and SCHMIDT's) were only presented by drawings, without providing descriptions. The first morphological description of *G. tergestinum* was published by HUSTEDT (1930), based on samples collected in standing waters in Gülzow and in Jezioro Śremskie (Poland). Later KRAMMER & LANGE-BERTALOT (1986) presented a more complete description of its ultrastructure, distribution and ecology. According to KRAMMER & LANGE-BERTALOT (1986), *G. tergestinum* has been mainly found in oligotrophic to low mesotrophic lakes with high conductivity (e.g. Lago di Garda in the calcareous Southern Alps). More recently, VAN DAM et al. (1994) considered it to be a euryhaline, alkaliphilous, oligosaprobous, oligo-mesotraphentic and nitrogen-autotrophic taxon, tolerating very low concentrations of organically bound nitrogen. Afterwards, LANGE-BERTALOT (1996) suggested *G. tergestinum* as a presumably endangered taxon in Germany, occurring in oligotrophic and mainly calcareous water bodies. Distribution of *G. tergestinum* was not entirely known until 1986, since it has only been found in a few sites in Europe, Asia and North America (KRAMMER & LANGE-BERTALOT 1986). However, considering the currently available references on the occurrence of this taxon, there is a vast set of publications referring to the distribution of this *Gomphonema* from numerous freshwater sites all around the world (see Figure 4.13, world distribution map for detail).

Two other taxa belonging to the same group and whose identification can be problematic due to similarities with *G. rosenstockianum* and *G. tergestinum* are *G. angustius* E. Reichardt and *G. supertergestinum* E. Reichardt. *Gomphonema angustius* was recently described from Germany (REICHARDT 2009). To date, the occurrence of *G. angustius*, according to REICHARDT (2009), is limited to highly calcareous streams in the Franconian Jura, in the Northern Alps of Switzerland and in Sicily. *G. supertergestinum* was described from Germany (REICHARDT 2009); this is considered as an independent species although it has already been represented by several authors, e.g. in SCHMIDT et

al. (1902), HUSTEDT (1930), and VAN DER WERFF & HULS (1957-1974); nevertheless, according to REICHARDT (2009), in those works it has not been distinguished from *G. tergestinum*.

The main aim of this study is to increase the knowledge about the taxonomy of the *Gomphonema rosenstockianum – G. tergestinum* species complex and to document the morphological differences of the species. To achieve this aim we relied on the analysis in LM and SEM of epilithic diatom samples collected in rivers from different European countries and the type material of *G. rosenstockianum* from Canary Islands, on a valve shape analysis by means of geometric morphometry, and on the verification of the stability of the morphological characters throughout the life cycle of *G. rosenstockianum* through the study of monoclonal cultures from samples collected in South of Portugal streams. Additionally, *G. angustius* and *G. supertergestinum* are characterized and illustrated in detail by LM and SEM with additional references to the distribution of both species. Furthermore, it is aimed to present the world distribution of the four species studied through the analysis of bibliographic information and the epilithic samples studied.

4.2.2 Materials and methods

Observations are based on the original type material of *Gomphonema rosenstockianum* obtained from the LANGE-BERTALOT Collection, Eu-E 56, Botanik Institut Universität Frankfurt am Main, collected by H. GRASMÜCK (March 1988) in Bosque del Cedro, La Gomera, Canary Islands, Spain.

The type material of *G. semiapertum* var. *tergestina* Grunow has not been found so far, neither at the GRUNOW Diatom Collection at the Naturhistorisches Museum Wien (Curator: Dr. Anton Igersheim) nor at the National Botanic Garden of Belgium in Meise (Curator: Dr. Bart Van de Vijver). Thus, GRUNOW's drawing in plate 25, fig. 40 in VAN HEURCK (1880) represents the only available information about the type of this species. The drawing of the type of *G. semiapertum* var. *tergestina* made by A. GRUNOW, M. SCHMIDT's illustrations of *G. tergestinum* presented in plate 234, figs 41-43 in SCHMIDT et al. (1902), and the LM and SEM images shown in REICHARDT & LANGE-BERTALOT (1991) were the basis used to define the concept of the species.

Moreover, epilithic diatom samples from Bulgaria, France, Hungary, Italy, Portugal, Slovakia and Spain were also analysed in LM and SEM. Details of the sampling sites are presented in Table 4.1. Additionally, monoclonal cultures of *G. rosenstockianum* were obtained from three samples collected in December 2006 from streams of the Algarve, South of Portugal.

Type material, field samples and monoclonal cultures were treated using hot hydrogen peroxide (120 vols.) and diluted HCl (37%), in order to obtain a suspension of clean frustules. Permanent slides were mounted with Naphrax®. LM observations and morphometric measurements were performed using a Leica® DMRX light microscope with 100x oil immersion objective and light microscopy photographs were taken with a Leica® DC500 camera. Samples selected for scanning electron microscopy analysis were filtrated through polycarbonate membrane filters with a pore diameter of 3 µm, mounted on stubs, sputtered with gold (40 nm) with Modular High Vacuum Coating System (BAL-TEC MED 020) and studied with a Leica® Stereoscan 430i, operated at 20 kV.

Table 4.1. Sampling sites characteristics. Coordinates referred to the WGS84 datum.

Species / Sites	Sampling date	Latitude	Longitude	Altitude (m a.s.l.)	Conductivity ($\mu S \cdot cm^{-1}$)	pH
G. rosenstockianum Lange-Bert. & E. Reichardt						
Arão Stream, Pereira, Algarve (Portugal)	06/05/2006	37º 09' 31" N	8º 36' 13" W	24	303	8.9
Algibre Stream, Tôr, Algarve (Portugal)	17/04/2006	37º 11' 23" N	8º 01' 37" W	124	236	8.4
Son Brull Stream, Pollença, Mallorca Island (Spain)	10/12/2005	39º 52' 55" N	3º 01' 11" E	55	733	7.7
Puigpunyent Stream, Puigpunyent, Mallorca Island (Spain)	19/02/2006	39º 37' 18" N	2º 31' 38" E	215	1174	7.9
G. tergestinum (Grunow) M. Schmidt						
Cant Stream, Biancot, Cuneo (Italy)	29/11/2006	44º 20' 57" N	7º 10' 26" E	1470	692	8.1
Germanasca Stream, Ghigo di Prali, Torino (Italy)	07/12/2006	44º 53' 31" N	7º 02' 53" E	1450	167	8.0
Payant Stream, Bobbio Pellice, Torino (Italy)	05/12/2006	44º 48' 20" N	7º 07' 05" E	734	112	8.2
Drôme River, Charens, Rhone Alps (France)	15/09/1997	44º 32' 18" N	5º 30' 33" E	849	398	8.3
Danube River, Karlova Ves (Slovakia)	10/04/2006	48º 08' 39" N	17º 03' 30" E	140	496	8.4
Lomnica River, Juskova Vola (Slovakia)	16/04/2004	48º 52' 43" N	21º 34º 07" E	253	17.8	7.7
Isuela River, Cálcena, Zaragoza (Spain)	27/07/2003	41º 39' 15" N	1º 43' 03" W	817	No data	No data
Araquil River, Asiaín, Navarra (Spain)	16/08/2003	42º 49' 52" N	1º 47' 17" W	394	375	8.5
Esca River, Sigües, Zaragoza (Spain)	17/08/2003	42º 37' 48" N	1º 00' 55" W	506	300	8.5
Arga River, Huarte, Navarra (Spain)	18/08/2003	42º 49' 52" N	1º 35' 09" W	443	223	8.3
G. angustius E. Reichardt						
Arba de Biel River, Luna, Zaragoza (Spain)	29/07/2003	42º 09' 32" N	0º 55' 42" W	447	450	7.9
G. supertergestinum E. Reichardt						
Nela River, Cigüenza, Villarcayo Burgos (Spain)	16/08/2003	42º 56' 33" N	3º 34' 27" W	597	250	8.0
Danube main arm, Göd (Hungary)	08/02/2006	47º 41' 36" N	19º 07' 47" E	103	582	8.6

For the valve shape analysis, 15 landmarks were placed along the valve outline and at the curvature extremes, at the end of the striae delimiting the central area, and on the stigma (Figure 4.1) and digitized using tpsDig2 software (ROHLF 2004). The Cartesian coordinates of the cells were aligned (translated, rotated and scaled) by the Procrustes generalized orthogonal least-squared superimposition procedure (Generalized Procustes Analysis, GPA, ROHLF & SLICE 1990). Thin-plate spline deformations in landmark configuration relative to a theoretical average configuration representing the consensus form of the valve shape were calculated. A Principal Component Analysis (PCA) was carried out on the tangent space Procrustes coordinates by means of the software Past version 1.78 (HAMMER et al. 2001). Afterwards a Hotelling's T-square statistic was performed on the PCA scores of the specimens in the first two axes to account for significant morphological differences among the *a priori* established groups, this test being a generalization of Student's t statistic that is used in multivariate hypothesis testing (HOTELLING 1931). We evaluated 50 light microscope photographs of *G. rosenstockianum* for the valve shape analysis, including the type material and the populations of the South of Portugal and Mallorca Island (Spain) and 50 light microscope photographs of *G. tergestinum* from Italy, Slovakia and Spain.

Based on the bibliographic information available and on the distribution of the taxa present in the epilithic river samples analysed in this study, a world distribution map of *G. rosenstockianum*, *G. tergestinum*, *G. angustius* and *G. supertergestinum* has been performed using GIS software.

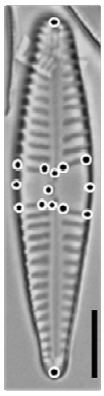

Figure 4.1 Light micrograph of *Gomphonema tergestinum* showing the position of the 15 landmarks on the valve outline used to perform the morphometric analysis.
Scale bar = 5 μm.

4.2.3 Results

4.2.3.1 *Gomphonema rosenstockianum* Lange-Bert. & E. Reichardt in Lange-Bert. 1993

Figure 4.2: LM, Figure 4.3 and Figure 4.4: SEM

References and illustrations

The type of the species has only been illustrated by LANGE-BERTALOT (1993, p. 71, pl. 76, figs 1-8: LM, figs 9, 10: SEM).

Morphological examination

Type material: Figure 4.2 a-l: LM, Figure 4.3: SEM

Populations from river epilithic samples: Figure 4.2 m-aap: LM, Figure 4.4: SEM

Specimens of *G. rosenstockianum* were abundant in the type material from Canary Islands and the examination of the type population allowed the definition of the following features: valve outline is always sublinear-elliptic to elliptic in smaller individuals, striae are slightly radiate to almost parallel in the proximity of the central area (Figure 4.2 a-l). Only one short stria is located on the stigma-bearing side, on the opposite side to the unilaterally expanded central area (Figure 4.2 a-l). The ranges of width, length, and density of striae are given in Table 4.2. Observed in SEM, the stigma is covered by a papilla and does not present a collar-like ring around its aperture in internal view (Figure 4.3 e), striae consist of one row of areolae although sometimes the areolae can be arranged in a double row in the proximity of the raphe (Figure 4.3 a). Areolae are covered by papillae (Figure 4.3 c).

A comparison between the epilithic samples from South of Portugal (Figure 4.2 - m-an: LM, Figure 4.3: SEM) and Mallorca, Balearic Islands, Spain (Figure 4.2 ao-aap: LM) with the type material (Canary Island, Spain) showed a constancy of morphological characteristics. Nevertheless, the populations from the river epilithic samples presented smaller individuals and higher density of striae than the type material (Table 4.2). LM and SEM examination of the monoclonal cultures from stream samples of South of Portugal allowed the observation of the stability of the characteristics throughout the life cycle. Namely, in LM the valve outline was always sublinear-elliptic to elliptic in smaller individuals, striae were slightly radiate to almost parallel in the proximity of the central area and the presence of only one short stria on the stigma-bearing side, opposite to the unilaterally expanded central area. In SEM, the stigma was covered by a papilla and lacked a collar-like ring around its aperture (in internal view). The striation was formed by one range of areolae internally covered by papillae.

Ecological data

The geographical and chemical characterization of the sites from where the populations of *Gomphonema rosenstockianum* illustrated in this study were collected is presented in Table 4.1. This epilithic diatom was found with abundance over 2.5% in several Portuguese streams with a range of pH between 6.5 and 9.2, conductivity between 146 and 600 $\mu S \cdot cm^{-1}$ and dissolved oxygen between 6.6 and 13.0 $mg \cdot L^{-1}$, while the two streams of Mallorca Island (Spain) with presence of *G.*

rosenstockianum are characterized by a pH between 7.5 and 8.0, a conductivity between 732-1601 $\mu S \cdot cm^{-1}$ and dissolved oxygen between 6.2-10.4 $mg \cdot L^{-1}$.

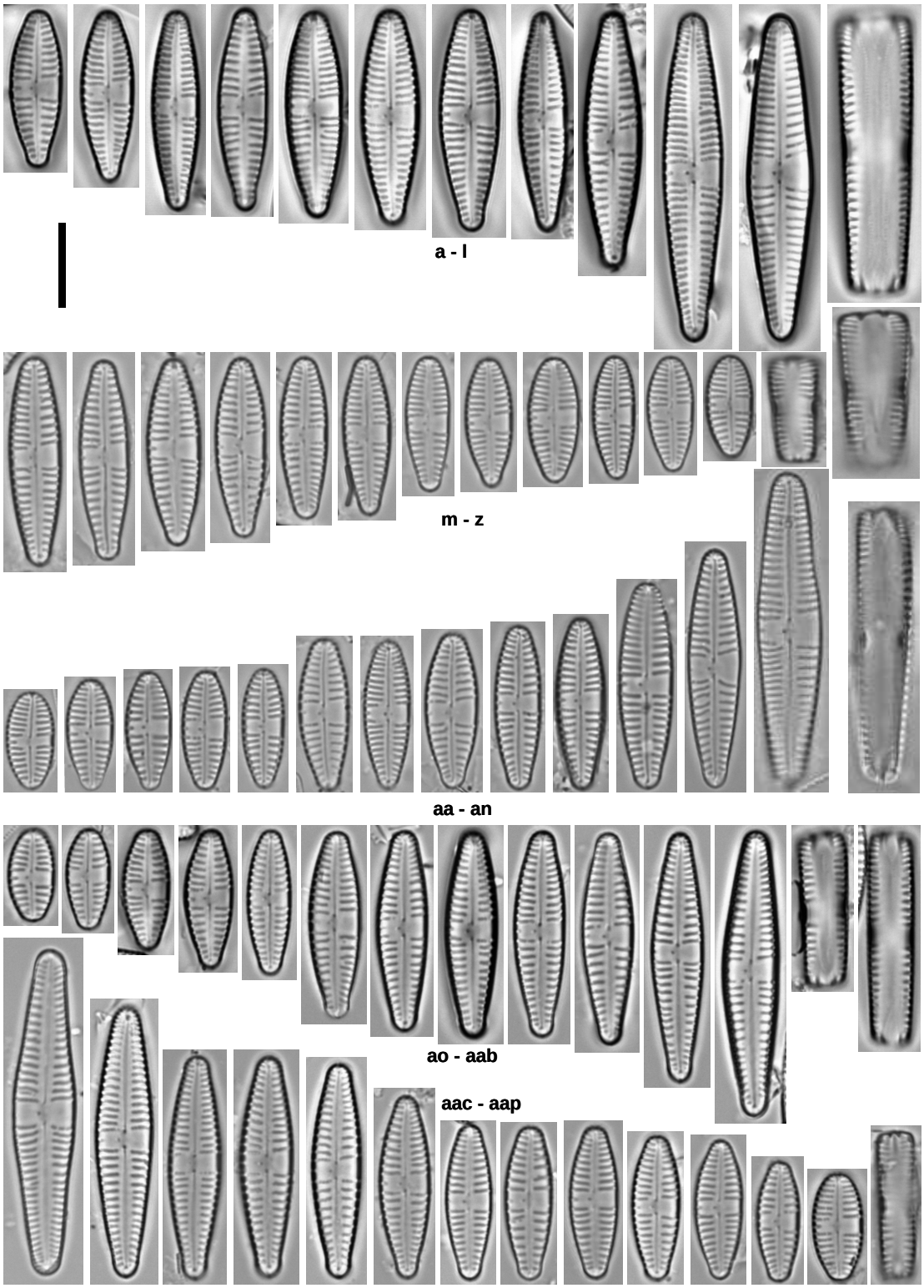

Figure 4.2 Light micrographs of *Gomphonema rosenstockianum*. (a-l) Type material, La Gomera, Canary Islands, Spain. (m-z) Arão Stream, Pereira, South of Portugal. (aa-an) Algibre Stream, Tôr, South of Portugal. (ao-aab) Son Brull Stream, Pollença, Mallorca, Spain. (aac-aap) Puigpunyent Stream, Puigpunyent, Mallorca, Spain.
Scale bar = 10 µm.

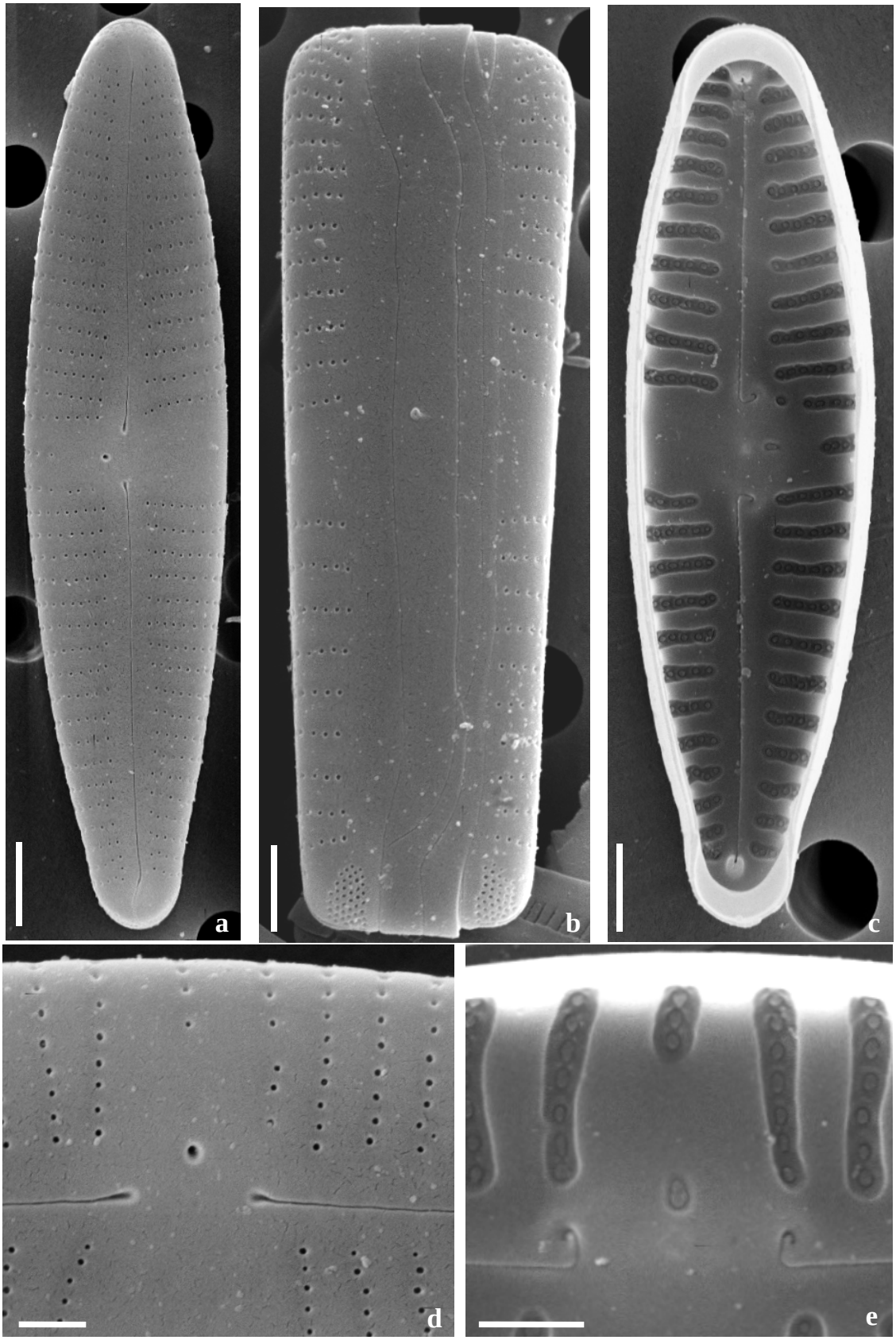

Figure 4.3 Scanning electron micrographs of the type material of *Gomphonema rosenstockianum*, La Gomera, Canary Islands, Spain. (a) Valvar view (external view). (b) Girdle view (external view). (c) Valvar view (internal view), showing the uniseriate striation and the areolae covered by papillae. (d, e) Details of the central area in external (d) and internal (e) views.
Scale bars (a-c) = 2 µm. Scale bars (d, e) = 1 µm.

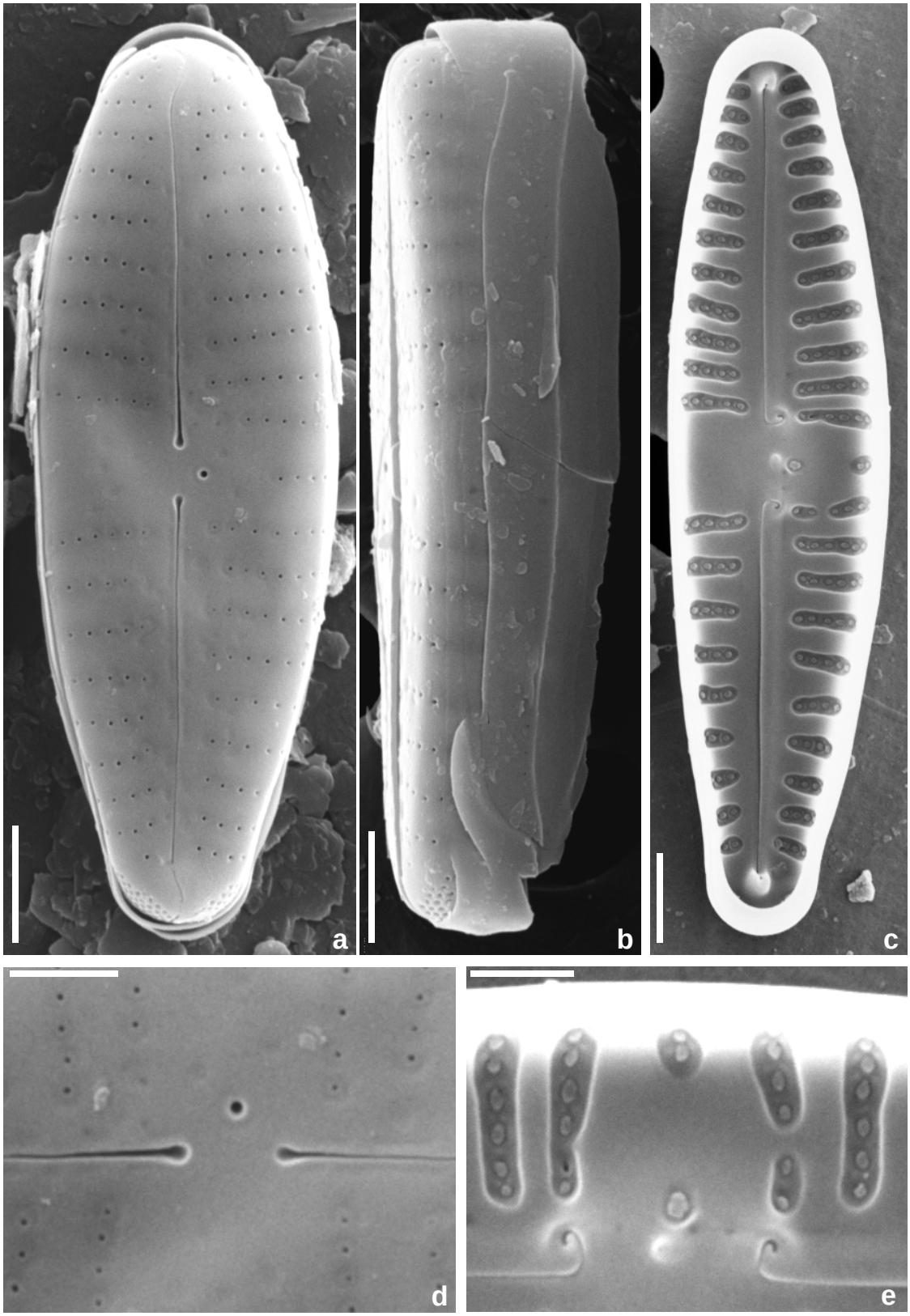

Figure 4.4 Scanning electron micrographs of *Gomphonema rosenstockianum* from Arão Stream, Pereira, South of Portugal. (a) Valvar view (external view). (b) Girdle view (external view). (c) Valvar view (internal view). (d, e) Details of the central area in external (d) and internal (e) views.
Scale bars (a-c) = 2 µm. Scale bars (d, e) = 1 µm.

Table 4.2 Morphometric data of the *Gomphonema* studied (underlined = type material). Sample size: *G. rosenstockianum*, n = 61; *G. tergestinum*, n = 148; *G. angustius*, n = 12; *G. supertergestinum*, n = 16.

Species / Sites	**Length (μm)**	**Width (μm)**	**N° striae / 10 μm**
***G. rosenstockianum* Lange-Bert. & E. Reichardt**			
La Gomera, Canary Islands (Spain)	16.7 – 34.0	4.9 – 6.3	10 – 13
Arão Stream, Algarve (Portugal)	10.1 – 29.6	4.8 – 5.7	12 – 16
Algibre Stream, Algarve (Portugal)	10.1 – 32.8	4.5 – 6.1	12 – 15
Son Brull Stream, Mallorca Island (Spain)	9.7 – 29.7	4.6 – 5.8	11 – 15
Puigpunyent Stream, Mallorca Island (Spain)	10.9 – 34.0	4.4 – 6.2	10 – 17
***G. tergestinum* (Grunow) M. Schmidt**			
Trieste (Italy)	14.0	3.5	14
Cant Stream, Cuneo (Italy)	11.1 – 30.1	4.1 – 6.0	11 – 14
Germanasca Stream, Torino (Italy)	11.4 – 32.7	4.3 – 6.3	10 – 16
Payant Stream, Torino (Italy)	11.1 – 30.1	4.1 – 6.0	11 – 14
Drôme River, Charens, Rhone Alps (France)	11.6 – 26.6	4.0 – 5.3	11 – 15
Danube River (Slovakia)	9.5 – 26.4	4.4 – 5.7	11 – 15
Lomnica River (Slovakia)	12.3 – 26.4	4.9 – 6.0	10 – 16
Isuela River, Zaragoza (Spain)	9.9 – 23.3	3.6 – 5.4	10 – 14
Araquil River, Navarra (Spain)	13.4 – 20.1	5.0 – 6.5	11 – 15
Esca River, Zaragoza (Spain)	12.6 – 20.1	4.2 – 5.9	10 – 14
Arga River, Huarte, Navarra (Spain)	13.3 – 29.7	5.1 – 6.0	12 – 14
Ebro River, San Adrián, Navarra (Spain)	10.0 – 20.7	4.7 – 6.3	12 – 14
Arga River, Embalse Eugui, Navarra (Spain)	8.7 – 20	4.7 – 5.8	9 – 14
***G. angustius* E. Reichardt**			
Kurzenaltheim, Lkr. WUG, Bavaria (Germany)	10.3 – 26.0	4.0 – 5.6	10 – 12
Arba de Biel River, Luna, Zaragoza (Spain)	14.8 – 35.0	4.2 – 6.9	8 –10
***G. supertergestinum* E. Reichardt**			
Boitzenburg, Uckermark, Brandenburg (Germany)	22.0 – 52.0	7.0 – 9.8	9 – 12
Nela River, Burgos (Spain)	28.1 – 38.7	7.0 – 8.0	10 – 11
Danube main arm, Göd (Hungary)	25.2 – 36.2	6.7 – 8.5	9 – 11

4.2.3.2 *Gomphonema tergestinum* (Grunow in Van Heurck) M. Schmidt in Schmidt et al. 1902

Figure 4.1, Figure 4.5, Figure 4.6: LM, Figure 4.7, Figure 4.8: SEM

Basionym: *Gomphonema semiapertum* var. *tergestina* GRUNOW in VAN HEURCK 1880, pl. 25, fig. 40

Nomenclatural synonyms: *Gomphonema parvulum* var. *tergestina* (GRUNOW in VAN HEURCK) CLEVE 1894, p. 181; *G. lanceolatum* f. *tergestina* (GRUNOW) CLEVE-EULER 1955, v. 5 (4): p. 185

Infraspecific taxa: *Gomphonema tergestinum* f. *subrostrata* MANGUIN 1964, p. 91; pl. 21, fig. 4; *Gomphonema tergestinum* var. *arcaliae* ROBERT 1969, v. 14 (2): p. 44; fig. 4a, b; these two infraspecific taxa (MANGUIN 1964, ROBERT 1969) are not similar to the nominate variety and are not included in this study.

References and illustrations

VAN HEURCK (1880, pl. 25, fig. 40: drawing, as *G. semiapertum* var. *tergestina* GRUNOW), SCHMIDT et al. (1902, pl. 234, figs 41-43: drawings, as *G. tergestinum* GRUNOW), CARTER (1960, pl. 2, figs 3-6: drawing, as *G. tergestinum* GRUNOW), ROBERT (1969, p. 44, fig. 3: LM, as *G. tergestinum* (GRUNOW) FRICKE), REICHARDT & LANGE-BERTALOT (1991, pl. 10, figs 14-16: LM, fig. 17: SEM, as *G. tergestinum* FRICKE), GÜTTINGER (1992, pl. 2.05.24-12, figs 1-6: SEM, as *G. tergestinum* FRICKE), LANGE-BERTALOT & METZELTIN (1996, p. 314, pl. 98, fig. 19: LM, as *G. tergestinum* GRUNOW), SIMS (1996, pl. 109, fig. 18: drawing, as *G. tergestinum* (GRUNOW in VAN HEURCK) FRICKE in A. SCHMIDT), HÜRLIMANN & NIEDERHAUSER (2007, pl. 21, figs 24-27: LM, as *G. tergestinum* (GRUNOW) M. SCHMIDT), LEVKOV et al. (2007, p. 486, pl. 166, fig. 19: LM, as *G. tergestinum* (GRUNOW) FRICKE), REICHARDT (2009, fig. 8: SEM, figs 82-87, 89-92: LM, as *G. tergestinum* (GRUNOW) M. SCHMIDT).

Taxonomical remarks

In SCHMIDT et al. (1902), the asterisks situated near the illustrations of G. tergestinum (figs 39-43) in the plate 234 (Tafel 234. Herausgegeben von Dr. Friedr. FRICKE) indicate that M. SCHMIDT is the author of these drawings in A. SCHMIDT's Diatom Atlas. For this reason, the correct name is G. tergestinum (GRUNOW) M. SCHMIDT and not G. tergestinum (GRUNOW) FRICKE, as stated in many references, e.g. HUSTEDT (1930) and LEVKOV et al. (2007).

Morphological examination

The ranges of length, width, and density of striae of *G. tergestinum* from the available information on the type material and the river epilithic samples are presented in Table 4.2. Morphological characteristics of the species, based on the literature and river epilithic populations studied, can be summarized as follows: a large central area expanded unilaterally to the valve-margin and presence

of a short stria on the opposite side of the central area; an isolated stigma positioned almost in between the proximal raphe ends (surrounded by a narrow collar-shaped ring in internal view in SEM); transapical striae radiate, mainly constituted by one row of areolae covered by papillae (clearly discernible in SEM).

The characteristics of the river epilithic populations studied (Figure 4.5, Figure 4.6: LM) correspond better to the illustrations of GRUNOW and M. SCHMIDT than to the description and illustration of HUSTEDT (1930) and the description of KRAMMER & LANGE-BERTALOT (1986), regarding the valve outline and ranges of length and width. The SEM micrographs (Figure 4.7, Figure 4.8) correspond well to the internal view presented by REICHARDT & LANGE-BERTALOT (1991) regarding to the presence of the opening of the stigma surrounded by a collar-shaped ring and the striae formed by one row of areolae covered by papillae. Nevertheless, the natural populations studied are slightly different from GRUNOW's iconotype because of the presence of one short stria in the stigma-bearing side instead of two not shortened striae.

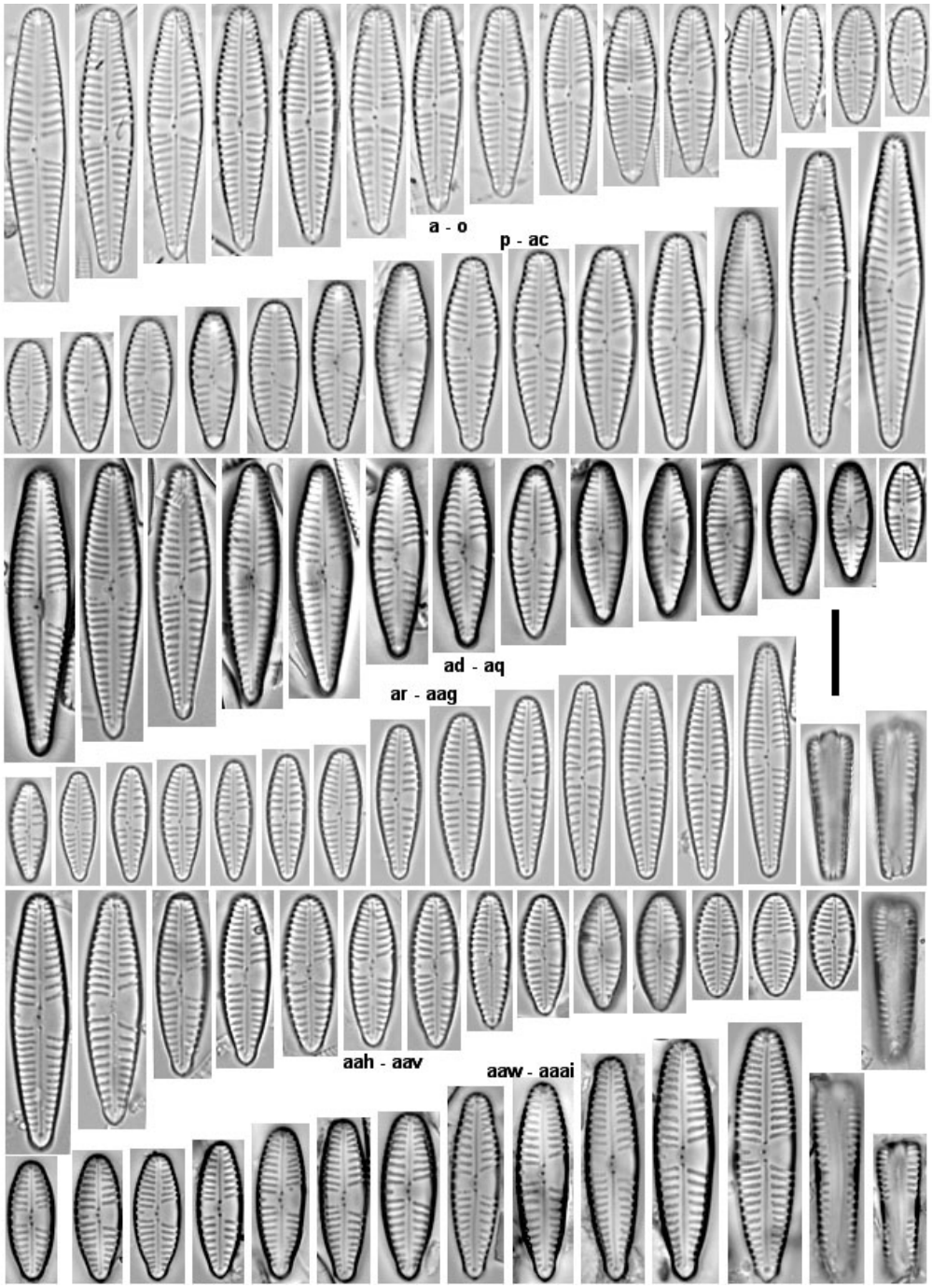

Figure 4.5 Light micrographs of *Gomphonema tergestinum*. (a-o) Cant Stream, Biancot (Cuneo), Italy. (p-ac) Germanasca Stream, Ghigo di Prali (Torino), Italy. (ad-aq) Payant Stream, Bobbio Pellice (Torino), Italy. (ar-aag) Drôme River, Charens (Rhone Alps), France. (aah-aav) Danube River, Karlova Ves, Slovakia. (aaw-aaai) Lomnica River, Juskova Vola, Eastern Slovakia.
Scale bar = 10 μm.

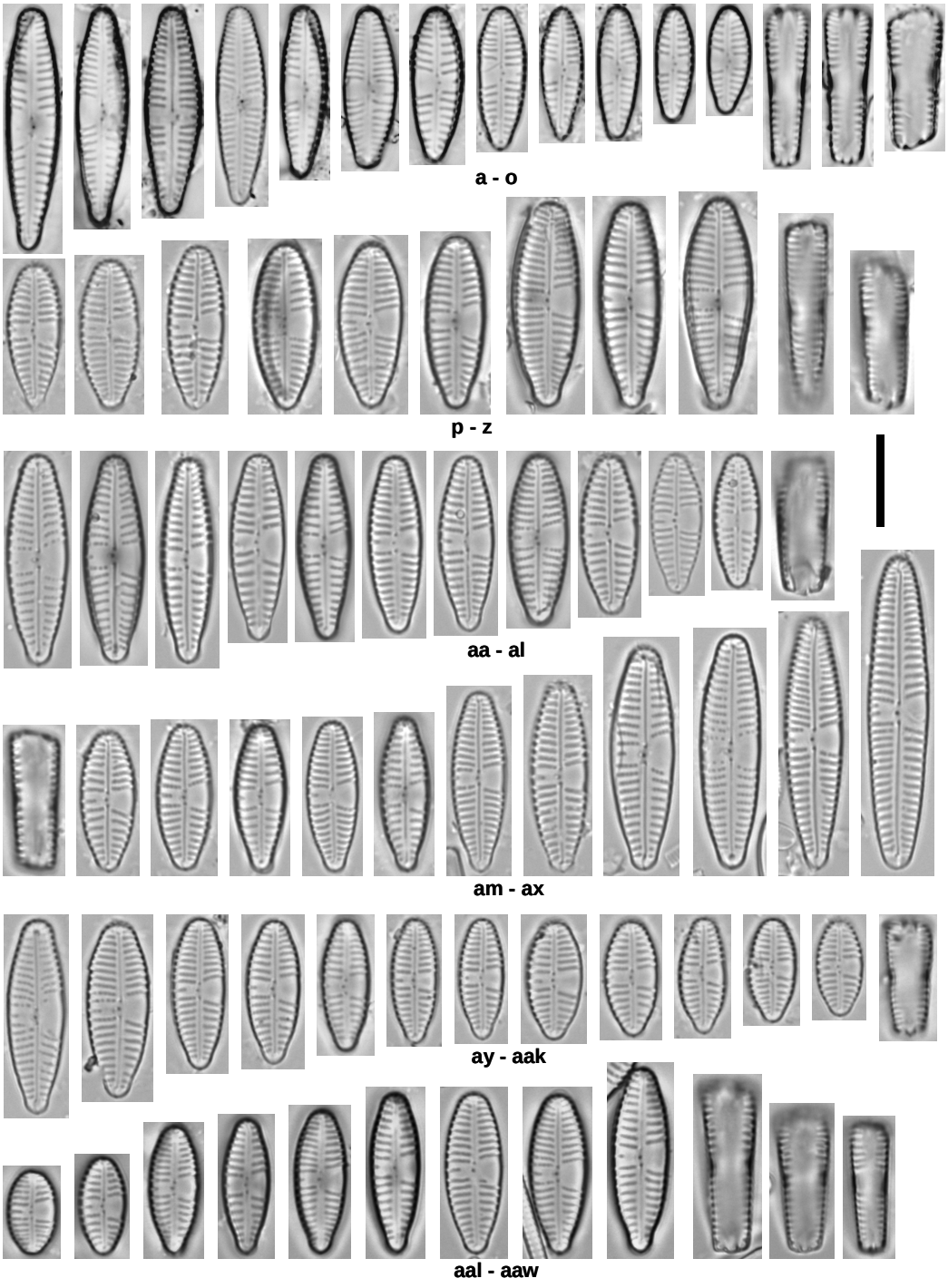

Figure 4.6 Light micrographs of populations of *Gomphonema tergestinum* from Spain. (a-o) Isuela River, Ermita de San Roque, Cálcena, Zaragoza. (p-z) Araquil River, Asiaín, Navarra. (aa-al) Esca River, Sigües, Zaragoza. (am-ax) Arga River, Huarte, Navarra. (ay-aak) Ebro River, San Adrián, Navarra. (aal-aaw) Arga River, Embalse Eugui, Navarra.
Scale bar = 10 μm.

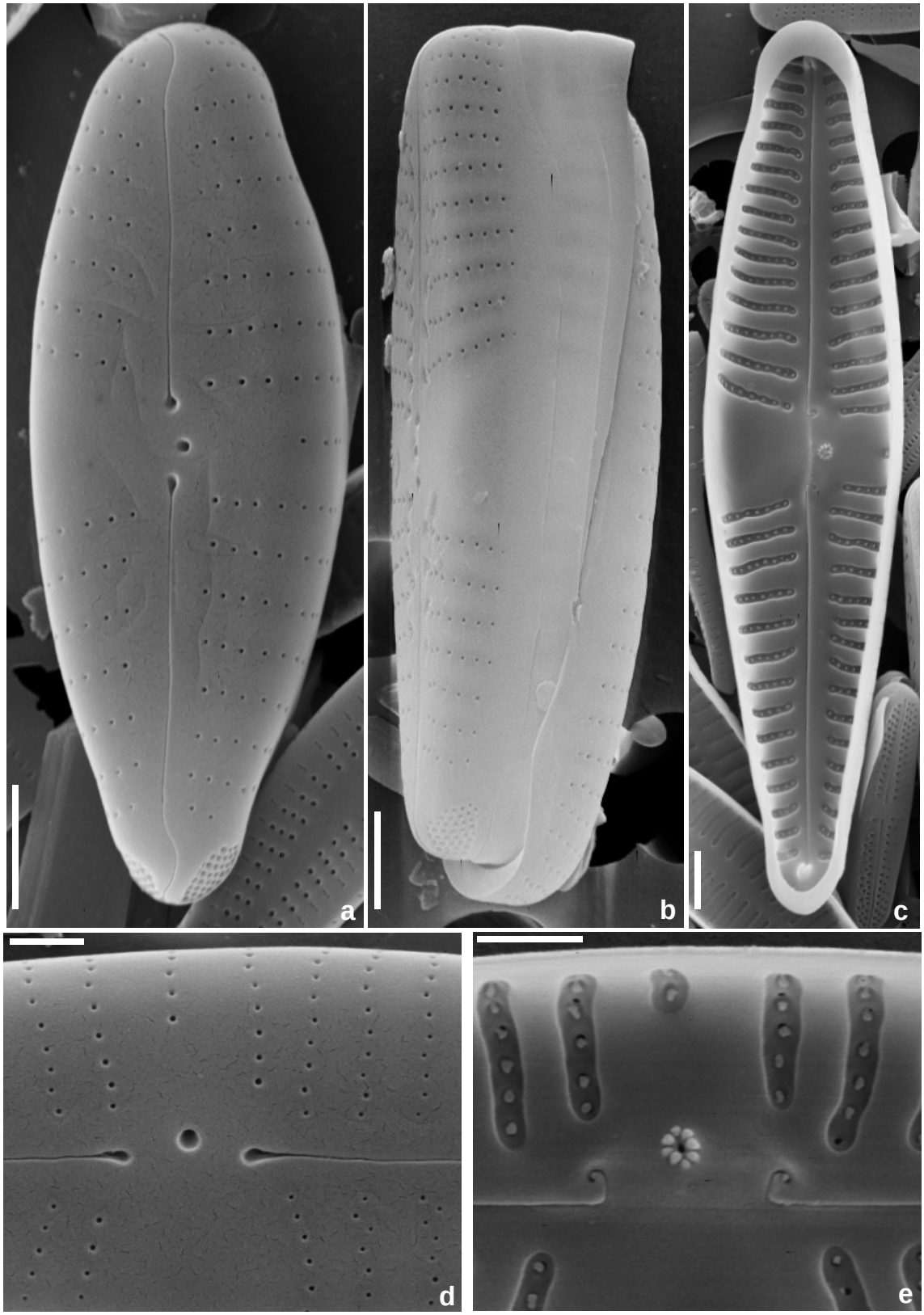

Figure 4.7 Scanning electron micrographs of *Gomphonema tergestinum* from Payant Stream, Bobbio Pellice, Torino, Italy. (a) Valvar external view. (b) Girdle external view from Fiumedinisi, Sicily, Italy. (c) Valvar internal view, showing the uniseriate striation and the areolae covered by papillae. (d, e) Details of the central area in external (d) and internal (e) view, presenting the stigma surrounded by a collar-shaped ring in internal view.
Scale bars (a-c) = 2 µm. Scale bars (d, e) = 1 µm.

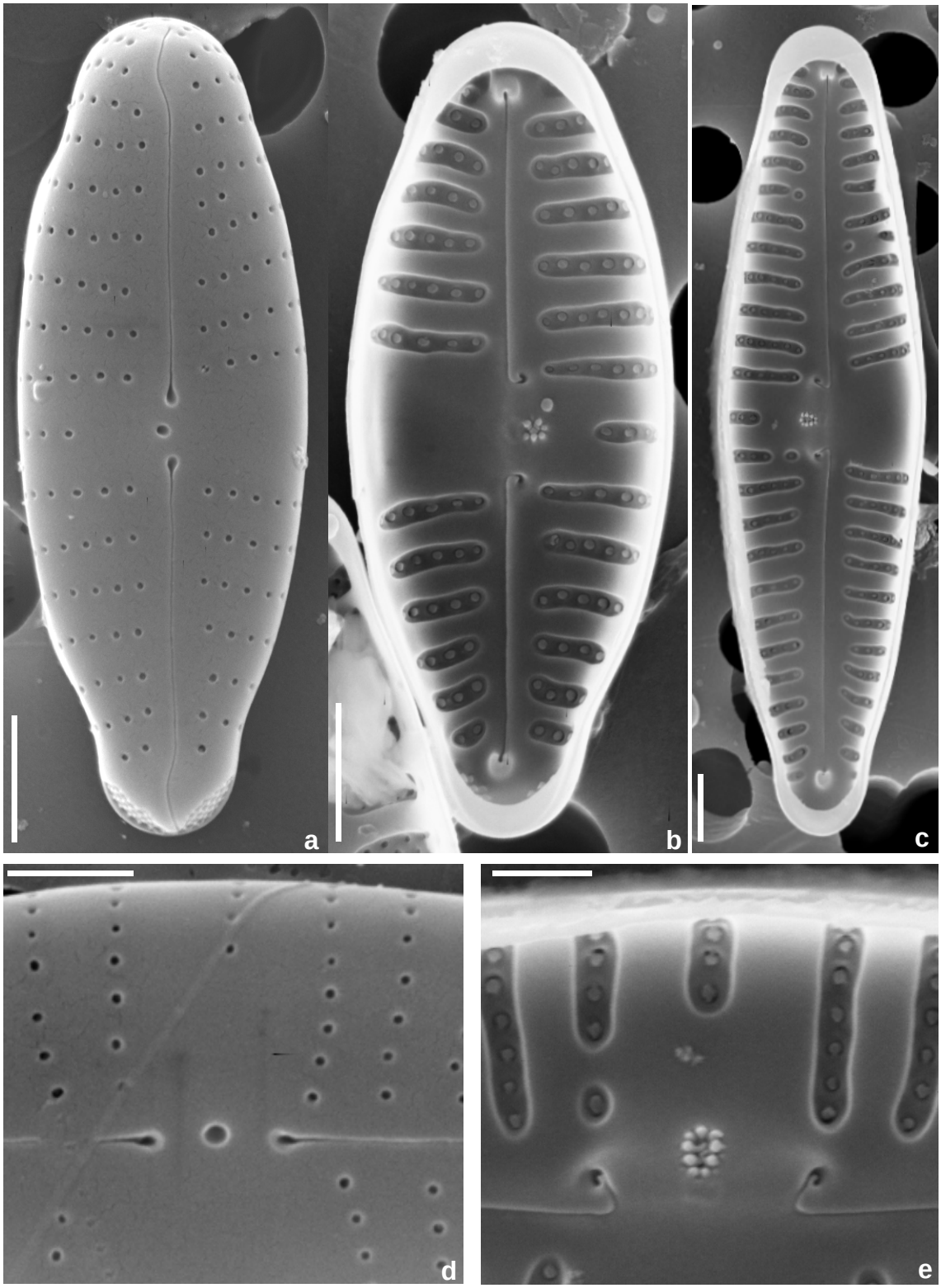

Figure 4.8 Scanning electron micrographs of *Gomphonema tergestinum* from Arga River, Embalse Eugui, Navarra, Spain. (a) Valvar external view. (b, c) Valvar internal view. (d, e) Details of the central area in external (d) and internal (e) view.
Scale bars (a-c) = 2 µm. Scale bars (d, e) = 1 µm.

4.2.3.3 Geometric morphometric analysis

A geometric morphometric analysis was performed in order to justify the separation of *Gomphonema rosenstockianum* and *G. tergestinum* based on the valve outline, the relative dimensions of the central area and the position of the stigma. The results of the Principal Component Analysis on landmark normalized coordinates clearly demonstrated the differentiation between the two taxa, along the second PC axis (Figure 4.9), considering the dimensions of the central area and the position of the stigma, proving the validity of these morphological criteria. The explained variance for the first axis (PCA1) is 74.71% and is 9.15% for the second axis (PCA2). Comparing the morphometric data, there are highly significant differences between both species (Hotelling's multivariate discriminant test T^2; $p < 0.001$).

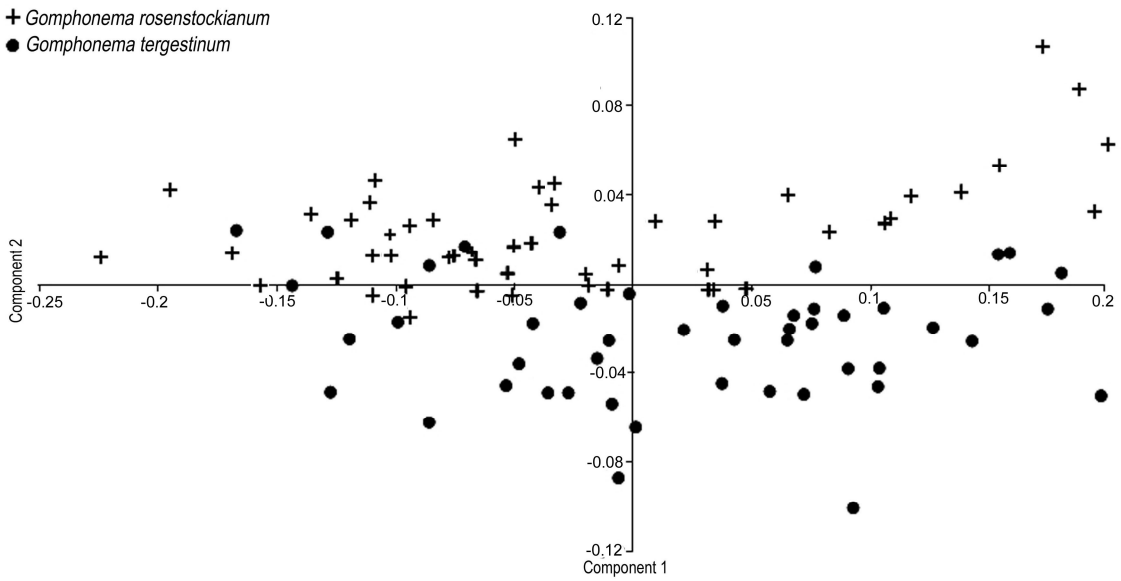

Figure 4.9 Principal Component Analysis (PCA) plot of normalized coordinates for the morphological landmarks digitized on LM images of selected populations of *Gomphonema rosenstockianum* and *G. tergestinum*.

4.2.3.4 *Gomphonema angustius* E. Reichardt 2009

Figure 4.10 a-m: LM, Figure 4.11: SEM

References and illustrations

This species has recently been described from Germany (Kurzenaltheim, Lkr. WUG, Bavaria) and is illustrated in REICHARDT (2009, figs 9-26: LM, figs 27-30: SEM).

Morphological examination

The population of *G. angustius* from Arba River, Zaragoza, Spain (Figure 4.10 a-m: LM, Figure 4.11: SEM) corresponds well to the description of the type from Bavaria, Germany by REICHARDT (2009). Nevertheless, the Spanish specimens are bigger, presenting a higher length (14.8-35.0 µm), a wider range of valve width (4.2-6.9 µm) and showing a lower density of striae (8-10 in 10 µm). The SEM analysis showed that the striae are composed by a double row of areolae with a certain tendency to be single-rowed in the proximity of the raphe near the central area (Figure 4.11 a, b); the striae are formed by round, dot-like areolae in external view; the areolae are not covered by papillae in internal view (Figure 4.11 c, e) and the internal opening of the stigma is surrounded by a collar-shaped ring (Figure 4.11 e). These ultrastructural characteristics are also present in the illustrations of the German type material provided by REICHARDT (2009). The morphometric characteristics of the river epilithic population studied are presented in Table 4.2.

During the present study, *G. angustius* has been found in Spain and Italy (Sicily) where it was never a dominant species and co-existed with *G. tergestinum*. In LM it can be distinguished either from *G. rosenstockianum* or from *G. tergestinum* by the valve outline and the lower density of striae and in SEM by the areolae not covered by papillae, arranged in a double row and by the opening of the stigma surrounded by a collar-shaped ring. This latter characteristic helps to distinguish this species only from *G. rosenstockianum*, being also a typical character to *G. tergestinum*.

4.2.3.5 *Gomphonema supertergestinum* E. Reichardt 2009

Figure 4.10 n-ae: LM, Figure 4.12: SEM

References and illustrations

This species has only recently been described from Germany (Hardenbecker Haussee in Boitzenburg, Uckermark, Brandenburg) and illustrated by REICHARDT (2009, figs 66-81: LM, figs 93-96: SEM).

Morphological examination

In this study, *Gomphonema supertergestinum* has been found in epilithic samples from several European watercourses from Bulgaria, Hungary, Slovakia and Spain, co-existing in some of them with *G. tergestinum.*

The populations of *G. supertergestinum* from Nela River (Burgos, Spain) (Figure 4.10 n-w: LM, Figure 4.12: SEM) and Danube River main arm (Göd, Hungary) (Figure 4.10 x-ae: LM) correspond well to the description of the species by REICHARDT (2009). However, the populations from Spain and Hungary are smaller (25.2-38.7 µm length, 6.7-8.5 width) than presented in the diagnosis of the

species and show a narrower range of density of striae (9-11 in 10 μm). Additionally, a row of poroids in the cingulum is visible in girdle view (Figure 4.10 w).

In SEM some characteristics referred to and illustrated by Reichardt (2009) are visible, like the pseudoseptum in the headpole (Figure 4.12 c), the striae composed by a double row of areolae with some tendency to be uniseriate near the raphe (especially the striae delimiting the central area) (Figure 4.12 d), the areolae not covered by papillae in internal view (Figure 4.12 e), the internal opening of the stigma surrounded by a collar-shaped ring (Figure 4.12 e) and the striae formed by round, dot-like areolae in external view (Figure 4.12 d).

The morphometric characteristics of the river epilithic populations studied are presented in Table 4.2.

Despite the co-occurrence of *G. supertergestinum* with *G. tergestinum*, it can be easily distinguished from *G. tergestinum* as well as from *G. rosenstockianum* in LM by the more robust valve outline, larger dimensions and lower density of striae in 10 μm in *G. supertergestinum*. In SEM the areolae not-covered by papillae and arranged in double rows can separate it from *G. tergestinum* and *G. rosenstockianum* while the internal opening of the stigma surrounded by a collar-shaped ring can help to differentiate it from *G. rosenstockianum*. The more robust valve outline and larger dimensions can facilitate the discrimination of this species from *G. angustius*. Morphometric and ultrastructural characteristics that allow the distinction between these four taxa are presented in Table 4.3.

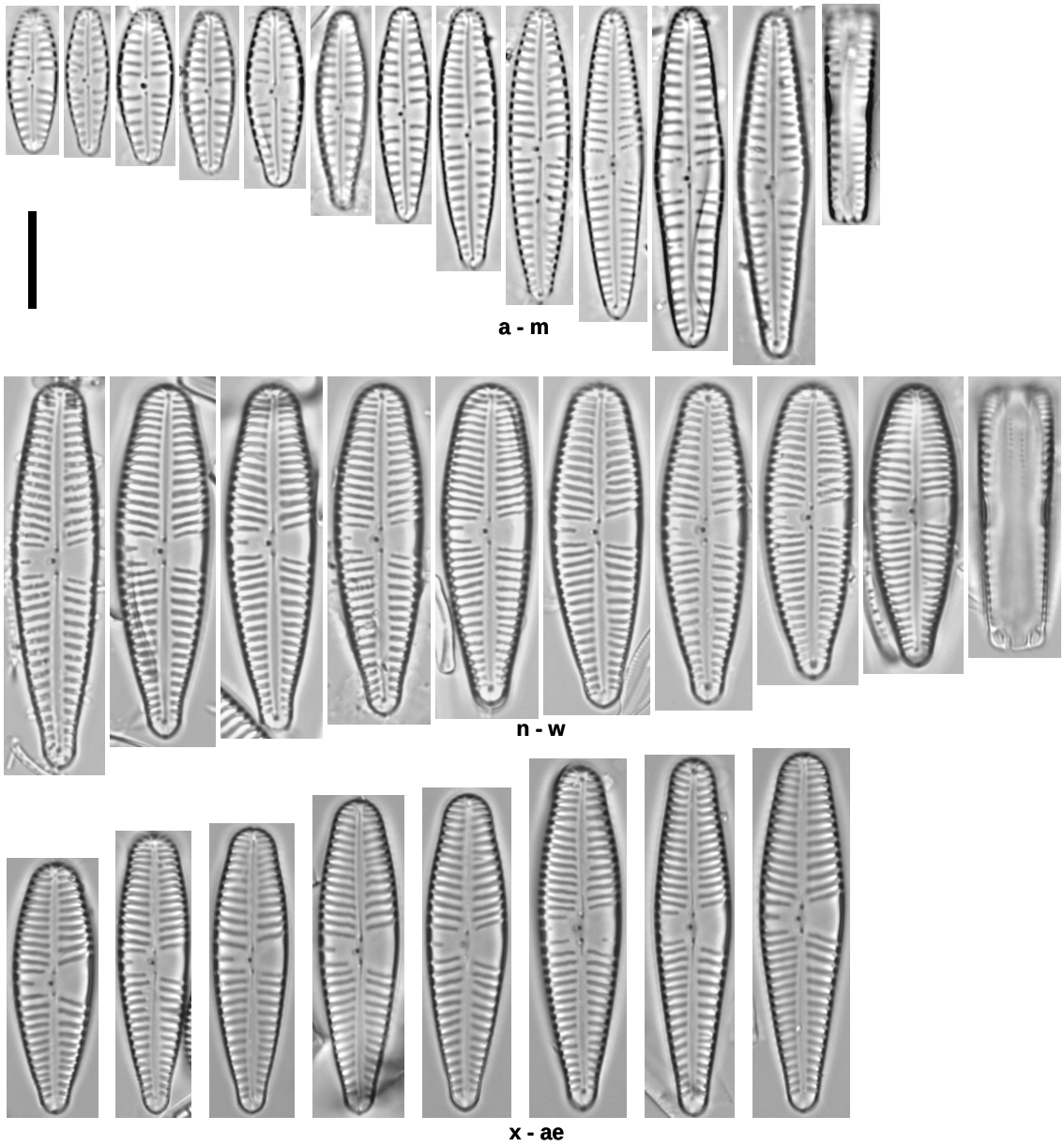

Figure 4.10 (a-m) Light micrographs of *Gomphonema angustius* from Arba de Biel River, Luna (Zaragoza), Spain. (n-ae) Light micrographs of *Gomphonema supertergestinum*. (n-w) Nela River, Cigüenza, Villarcayo (Burgos), Spain. (x-ae) Danube main arm, Göd, Hungary.
Scale bar = 10 µm.

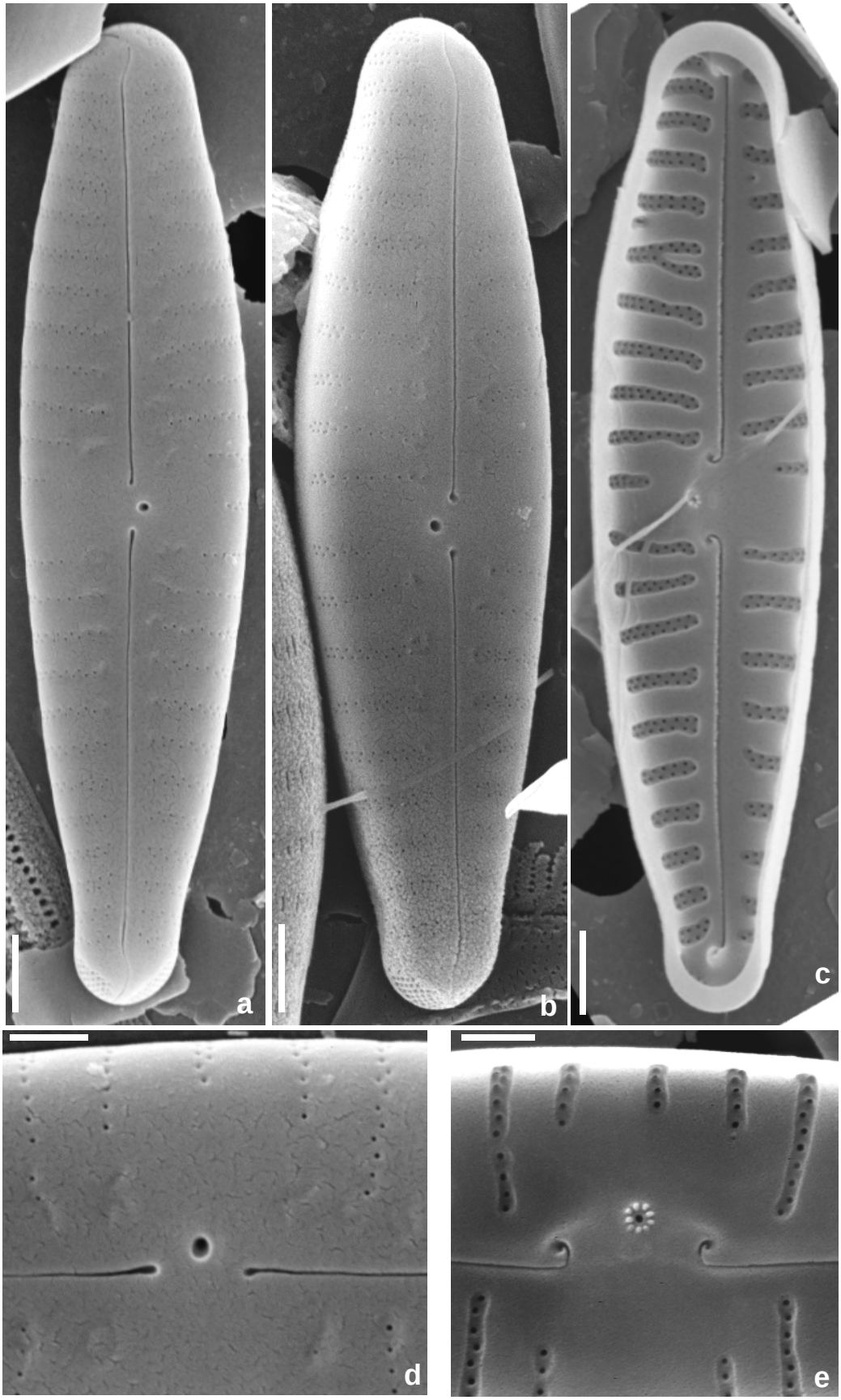

Figure 4.11 Scanning electron micrographs of *Gomphonema angustius* from Arba River, Biel in Luna (Zaragoza), Spain. (a, b) Valvar external view. (c) Valvar internal view. (d, e) Details of the central area in external (d) and internal (e) view.
Scale bars (a-c) = 2 µm. Scale bars (d, e) = 1 µm.

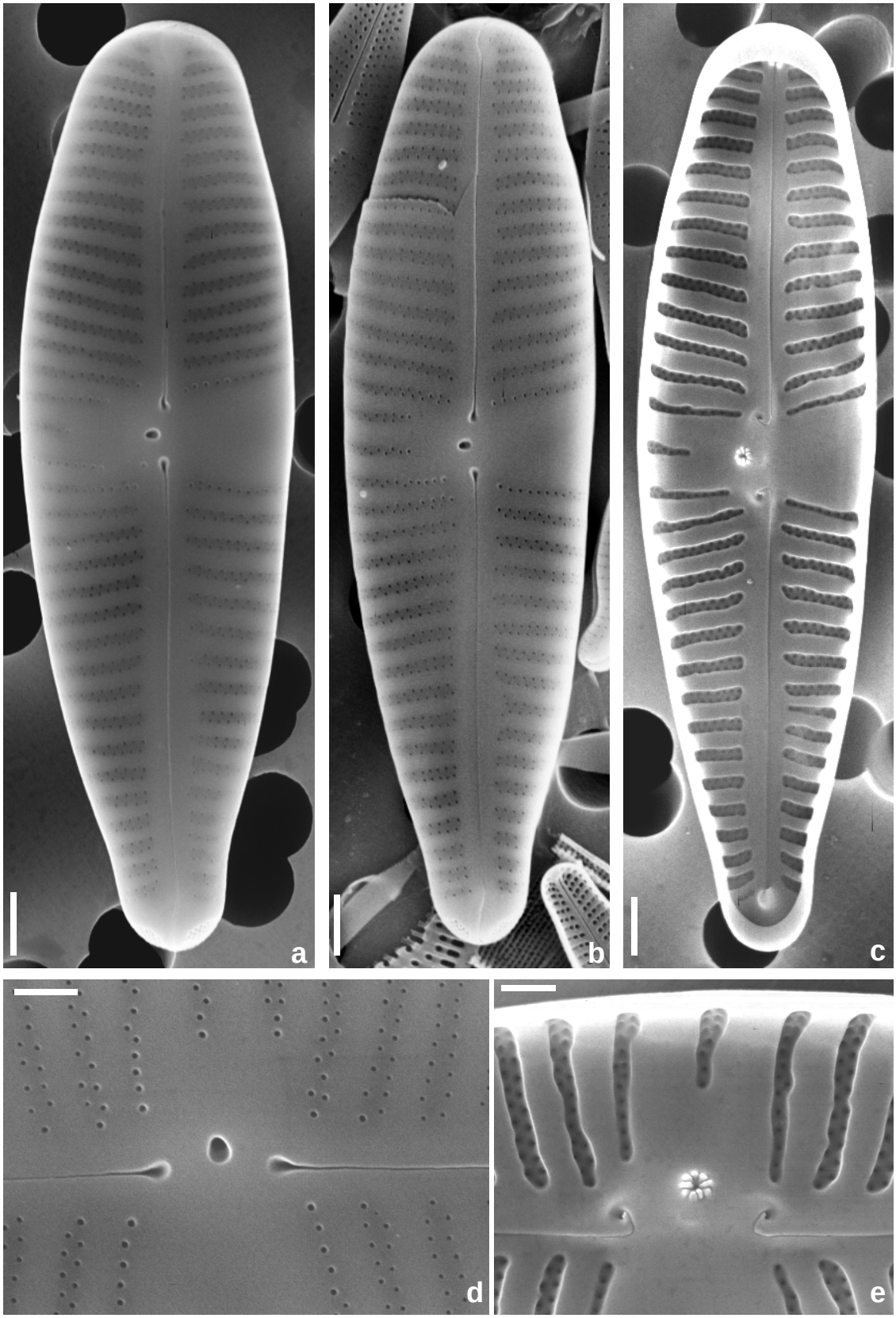

Figure 4.12 Scanning electron micrographs of *Gomphonema supertergestinum* from Nela River, Cigüenza, Villarcayo (Burgos), Spain. (a, b) Valvar external view, presenting the biseriate striation. (c) Valvar internal view. (d, e) Details of the central area in external (d) and internal (e) view, showing the areolae not covered by papillae and the stigma surrounded by a collar-shaped ring.
Scale bars (a-c) = 2 µm. Scale bars (d, e) = 1 µm.

Table 4.3 Ultrastructural and total range of morphometric data of the studied *Gomphonema*.

Species	Length (μm)	Width (μm)	N°striae / 10 μm	Stigma	Striation	Areolae
G. rosenstockianum Lange-Bert. & E. Reichardt	9.7 – 34.0	4.4 – 6.3	10 – 17	Covered by a papilla in internal view (SEM). Absence of collar-like ring in internal view (SEM)	Uniseriate on the mantle with tendency to biseriate on the proximity of the raphe	Covered by papillae in internal view (SEM)
G. tergestinum (Grunow) M. Schmidt	9.5 – 32.7	3.5 – 6.5	10 – 16	Collar-like ring in internal view (SEM)	Uniseriate on the mantle with tendency to biseriate on the proximity of the raphe	Covered by papillae in internal view (SEM)
G. angustius E. Reichardt	10.3 – 35.0	4.0 – 6.9	8 –12	Collar-like ring in internal view (SEM)	Biseriate	Not covered by papillae in internal view (SEM)
G. supertergestinum E. Reichardt	22.0 – 52.0	6.7 – 9.8	9 – 12	Collar-like ring in internal view (SEM)	Biseriate	Not covered by papillae in internal view (SEM)

4.2.3.6 Biogeography of *Gomphonema rosenstockianum* and *G. tergestinum* species complex

Subsequently to the revision of the literature published about this *Gomphonema* species complex, and taking into account the information provided by the analysis of the samples in this study, maps with world and European distribution of *G. tergestinum*, *G. rosenstockianum*, *G. angustius*, and *G. supertergestinum* have been performed, as shown in Figure 4.13 and Figure 4.14.

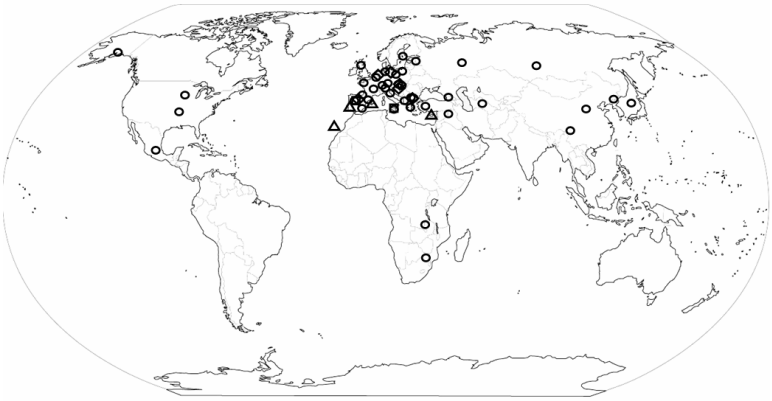

Figure 4.13 World distribution map of *Gomphonema rosenstockianum* (triangle), *G. tergestinum* (circle), *G. angustius* (square), *G. supertergestinum* (diamond).

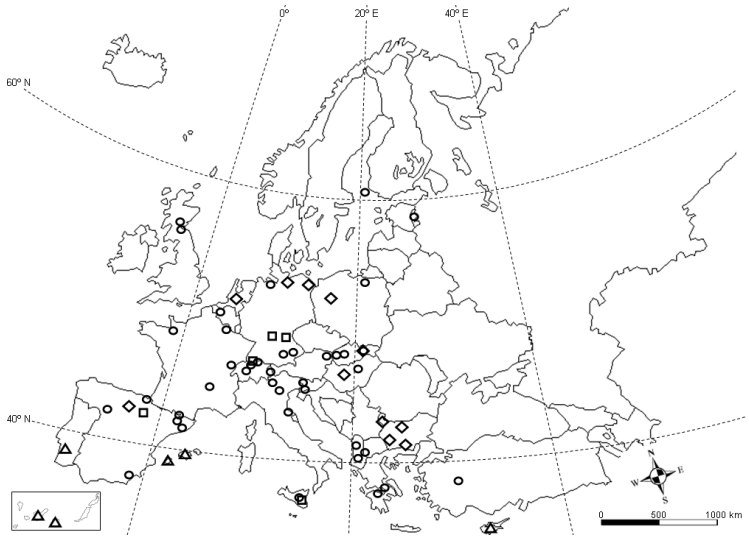

Figure 4.14 European distribution map of *Gomphonema rosenstockianum* (triangle), *G. tergestinum* (circle), *G. angustius* (square), *G. supertergestinum* (diamond).

4.2.4 Discussion and conclusions

The observations of type material, literature data and field populations from different European rivers made during this study allowed the identification of the following morphological criteria to reliably distinguish between *G. rosenstockianum* and *G. tergestinum*: 1) the presence of a collar-shaped ring around the opening of the stigma in internal view in *G. tergestinum* (only visible by SEM) and its absence in *G. rosenstockianum* (the stigma is instead covered by a papilla); 2) the more central position of the stigma situated almost in between proximal raphe ends in *G. tergestinum* (visible by LM and SEM on external view); 3) the more evident stigma in *G. tergestinum* (LM); 4) the presence of a wider central area in *G. tergestinum* with the striae of the central area more radiate while in *G. rosenstockianum* these striae are usually more parallel.

The geometric morphometric analysis proved to be a useful tool and allowed the validation of these criteria and the subsequent separation of both species. This approach has become a standard tool of taxonomic studies due to its higher capacity to distinguish shapes, and proved to be a useful tool in clarifying difficult species complexes such as *Achnanthidium* Kützing (POTAPOVA & HAMILTON 2007) or *Reimeria sinuata* and *Gomphonema tergestinum* (FRÁNKOVÁ et al. 2009).

The biogeography of these *Gomphonema* species can also be helpful in distinguishing them, since *G. rosenstockianum* has only been found in the Canary Islands and Mediterranean region (Balearic Islands, Cyprus and South of Portugal) (Figure 4.14) up to now. *G. tergestinum* seems to be widespread all over the world, although being mainly a palearctic species (Figure 4.13). As regards to the ecology of *G. rosenstockianum*, the analysis of the chemical parameters of the sites where the natural samples were collected allowed the confirmation of the information already provided by LANGE-BERTALOT (1993): *G. rosenstockianum* is an alcaliphilous species, mainly occurring in oligo- to β-mesosaprobic waters, although it can also be found in α-mesosaprobic waters. In the light of current presented results, several pictures of *G. rosenstockianum* referred from Bulgaria in reality belong to *G. tergestinum* (IVANOV et al. 2006a, figs 16-18; IVANOV et al. 2006b, pl. 7, figs 2, 3; STANCHEVA et al. 2007, pl. 3, figs 1-4).

Furthermore, the examination of the bibliographic references about *G. tergestinum* made clear that also the species *G. supertergestinum* has been previously incorrectly identified as *G. tergestinum* by SCHMIDT et al. (1902, figs 39, 40), HUSTEDT (1930, fig. 717), VAN DER WERFF & HULS (1957-1974), KRAMMER & LANGE-BERTALOT (1986, pl. 162, figs 6, 7), IVANOV et al. (2006*a*, p. 332, fig. 19), LEVKOV et al. (2007, pl. 166, fig. 17), and as *G. rosenstockianum* by IVANOV et al. (2006*b*, pl. 7, fig. 1) and STANCHEVA et al. (2007, pl. 3, figs 5, 6). Noticeably, most of these references correspond to lentic habitats, thus confirming the ecological preferences of *G. supertergestinum* for standing waters as noticed by REICHARDT (2009). Indeed the samples studied in this work were collected in large rivers, where sometimes the diatoms could only be collected near the margins, consequently in zones with low water flow and with more lentic characteristics.

Gomphonema angustius can be misidentified as *G. angustum* C. AGARDH or *G. occultum* E. REICHARDT & LANGE-BERT. in LM by the valve outline, similar striation pattern and position of the stigma. Although REICHARDT (2009) stated that *G. angustius* can be smaller (narrower) than *G.*

angustum, the population studied in this work was wider than the type material of *G. angustius*. Therefore, we conclude that these three species can only be distinguished with certainty in SEM. *G. angustius* differs from *G. angustum* and from *G. occultum* by the areolae not covered by papillae and arranged in double rows; additionally *G. angustius* is distinguished from *G. angustum* by the more recurved hook-shaped proximal raphe ends (REICHARDT & LANGE-BERTALOT 1991).

Regarding the general morphology of the species complex presented, mostly biseriate striation of *G. angustius* (Figure 4.11 a-c) and *G. supertergestinum* (Figure 4.12 a-c) could induce questions whether the placement of these species in the genus *Gomphonema* is justified. The taxonomic position of the double punctate species within the genera *Gomphonema* or *Gomphoneis* without longitudinal lines has already been discussed in the last decades, allowing different opinions. According to DAWSON (1974) and TUJI (2005), species presenting double rows of simple pores instead of the reniform poroidal structure typical of *Gomphonema* should be placed in the genus *Gomphoneis*. MERINO et al. (1994) also suggested the placement in the genus *Gomphoneis* of *Gomphonema rhombicum* M. SCHMIDT, based on the presence of septa and pseudosepta in the headpole and striae composed by double rows of single pores; however, the latter species lacks the longitudinal lines. Other authors, such as ISERENTANT & ECTOR (1996) and REICHARDT (2007), state that the arrangement of areolae in double rows is more common than has been suggested and can be found in all groups of the genus *Gomphonema*, even in taxa closely related to the generic type. Furthermore, *G. angustius* (Figure 4.11 a), *G. supertergestinum* (Figure 4.12 a, d) and also other species such as *Rhoicosphenia abbreviata* (C. AGARDH) LANGE-BERT. can even present both uniseriate and biseriate striae within the same valve (LANGE-BERTALOT 1980), which evokes doubts about the taxonomic relevance of this character alone on the generic level. Therefore we consider the criterion of double punctuation as not sufficient to place these species in the genus *Gomphoneis*.

Apart of double rows of simple pores, *G. supertergestinum* also presents a pseudoseptum in the bluntly rounded headpole; nevertheless, in our opinion, this species should be kept in the genus *Gomphonema*. The genus *Gomphoneis* is still not clearly defined since it is a rather heterogeneous group lacking reliable and clear characters to allow its differentiation from the genus *Gomphonema*, as pointed out by REICHARDT (2007).

From our study it becomes clear that there are recognizable differences in the ecological preferences of the taxa within this group, which can also serve as a helpful tool for the identification. It would thus be interesting to perform a similar study at a wider geographical scale, in order to increase and to support the current knowledge about the taxonomy, autoecology and biogeography of this species complex. Furthermore, it would be very useful to include the investigation of other species belonging to the same group, such as *G. angustum* and *G. occultum*.

4.2.5 Acknowledgements

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4.3 Morphology and ecology of *Achnanthidium caravelense* (Bacillariophyceae), a new species from Portuguese rivers

Abstract

A new benthic freshwater diatom species belonging to the genus *Achnanthidium* Kütz. has been recorded from several watercourses in the North of Portugal. *Achnanthidium caravelense* Novais et Ector is described as a new species based on light and scanning electron microscopic observations, as well as on its ecological preferences as reconstructed from field observations. The most characteristic morphological features of this species are the different outline of the raphe valve (narrowly elliptic with linear margins) and the rapheless valve (narrowly elliptic to narrowly rhombic with moderately convex margins), the non-protracted broadly rounded apices and the length/width ratio. Furthermore, the areolae of the single row along the mantle are elongated and are more or less widely open, which is a characteristic discernible in girdle view under light microscopy. The species that *A. caravelense* resembles most is *A. eutrophilum* (Lange-Bert.) Lange-Bert.; nevertheless it can be distinguished from the latter by the different raphe valve outline, its higher valve length/width ratio and autecology. *A. caravelense* is common and abundant in soft waters with low to moderate nutrient content in the North of Portugal.

Key words: *Achnanthidium caravelense*, *Achnanthidium eutrophilum*, Bacillariophyceae, diatoms, ecology, morphology, new species, Portugal, ultrastructure.

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4.3.1 Introduction

Species of the genus *Achnanthidium* Kützing are common and abundant in benthic communities, colonizing distinct substrates in diverse freshwater habitats (e.g. POTAPOVA & PONADER 2004, WOJTAL et al. 2010).

Achnanthidium has been restituted to genus rank by MANN (ROUND et al. 1990), since previously it was considered as a subgenus of *Achnanthes* Bory (e.g. PATRICK & REIMER 1966). Since then, the genus *Achnanthes* has been split into several genera, the genus *Achnanthidium* being confined by ROUND & BUKHTIYAROVA (1996) to the taxa morphologically similar to the generitype *A. microcephalum* Kützing. According to ROUND & BUKHTIYAROVA (1996), the genus *Achnanthidium* can therefore be characterized by its linear-lanceolate to lanceolate-elliptic valves, radial or almost transverse striae, which are uniseriate in SEM and coarser in the centre (especially in the raphe valve); cells in girdle view are shallow-V-shaped, the raphe valve presents a fine central raphe hardly expanded at the centre, straight or turned to one side at the apex and a row of slightly elongated areolae in the mantle.

Achnanthidium minutissimum sensu lato is one of the most frequent species within this genus and has been reported from acidic to alkaline and from oligotrophic to hypereutrophic waters, which has been questioned by several researchers and is considered a good example of a common species that needs further studies (ROUND 2004). Although the *A. minutissimum* complex has been recently a subject of more detailed studies (e.g. POTAPOVA & HAMILTON 2007), there are still gaps in the knowledge, especially of the ecological preferences of the species. ROUND (2004) pointed out that the current taxonomic system on diatoms often uses “aggregate” species, which comprise numerous forms with different ecological requirements.

During a survey of benthic diatoms sampled in watercourses from Mainland Portugal *Achnanthidium* frustules morphologically ascribable to the *A. minutissimum* complex and most similar to *A. eutrophilum* (LANGE-BERTALOT) LANGE-BERTALOT have been found. Since these individuals were present in numerous reference sites, a more detailed examination of the taxon was performed by means of light (LM) and scanning electron microscopy (SEM). Furthermore, the examination of the environmental characteristics of the sites where it has been sampled allowed us to gather sufficient information to propose this as a new species for science, being described and characterized hereby.

4.3.2 Material and methods

Benthic diatoms were sampled in spring and summer 2006 and 2007 in streams and rivers from Mainland Portugal. Epilithic diatom samples were treated by oxidation using hot hydrogen peroxide (35 %) and diluted HCl (37 %) in order to obtain a suspension of clean frustules. Permanent slides were mounted with Naphrax®. LM observations and morphometric measurements were performed using a Leica® DMRX brightfield microscope with 100 x oil immersion objective and light microscopy photographs were taken with a Leica® DC500 camera. Samples selected for scanning electron microscopy analysis were filtrated through polycarbonate membrane filters with a pore diameter of 3

µm, mounted on stubs using double sided carbon tape and sputtered with platinum (30 nm) with Modular High Vacuum Coating System (BAL-TEC MED 020) and studied with a Hitachi SU-70, operated at 5.0 kV.

Morphological terminology follows ROSS et al. (1979), ROUND et al. (1990) and KRAMMER & LANGE-BERTALOT (1991). For comparison, the following publications were consulted: CHOLNOKY (1957), CARTER & DENNY (1982), KOBAYASI & MAYAMA (1982), LANGE-BERTALOT & KRAMMER (1989), KRAMMER & LANGE-BERTALOT (1991), KOBAYASI (1997), MONNIER et al. (2004, 2007), POTAPOVA & PONADER (2004), IVANOV & ECTOR (2006), POTAPOVA (2006), BUKHTIYAROVA (2007), PONADER & POTAPOVA (2007), POTAPOVA & HAMILTON (2007), TAYLOR et al. (2007), MORALES et al. (2009), ZIDAROVA et al. (2009), HLUBIKOVA et al. (2011), VAN DE VIJVER et al. (2011a) and VAN DE VIJVER et al. (2011b).

To perform the morphometric analysis a total of 120 valves (60 raphe valves and 60 rapheless valves) of each species have been measured under the LM microscope with the 100 x oil immersion objective.

Ecological preferences of *Achnanthidium caravelense* and *A. eutrophilum* were inferred based on environmental variables from 74 sites from Mainland Portugal where these taxa have been found with a relative abundance above 1 % (31 sites for *A. caravelense* and 43 sites for *A. eutrophilum*). In total 20 environmental parameters were assessed by calculating the abundance weighted-average (WA): $N\text{-}NH_4^+$ (µg $N\text{-}NH_4^+$ L^{-1}), Cl^- (mg Cl^- L^{-1}), total organic carbon TOC (mg O_2 L^{-1}), total hardness (mg $CaCO_3$ L^{-1}), $P\text{-}PO_4^{3-}$ (µg $P\text{-}PO_4^{3-}$ L^{-1}), total phosphorus (µg P L^{-1}), soluble reactive phosphorus (SRP) (µg P L^{-1}), $N\text{-}NO_3^-$ (µg $N\text{-}NO_3^-$ L^{-1}), $N\text{-}NO_2^-$ (µg $N\text{-}NO_2^-$ L^{-1}), Na^+ (mg Na^+ L^{-1}), SO_4^{2-} (mg SO_4^{2-} L^{-1}), Ca^{2+} (mg Ca^{2+} L^{-1}), DO (% sat.), DO (mg L^{-1}), pH, conductivity (µS cm^{-1}), current velocity (m s^{-1}), altitude (m), catchment area (km^2) and distance from source (m). Standard methods for water chemical analysis were used according to APHA (1995).

The distribution map of *Achnanthidium caravelense* was generated using GIS software ArcGIS 9.3 (ESRI 2008). Statistical analysis for *A. caravelense* and *A. eutrophilum* morphometric data was performed by analysis of variance over the length/width ratio. Differences in ecological preferences were analyzed using only samples from streams (31 sites for *A. caravelense* and 30 sites for *A. eutrophilum*) since *A. caravelense* was not present in reservoirs. The analysis was performed using a weighted general multivariate model after variables normalization (natural logarithm). Statistical analyses were performed with SPSS software (SPSS 16.0 for windows, SPSS Inc. 1989-2007) and the graphical analysis was performed with the SigmaPlot® software v. 7.101 (SPSS INC. 2001).

4.3.3 Observations and discussion

***Achnanthidium caravelense* NOVAIS et ECTOR sp. nov.** (Figure 4.15)

DIAGNOSIS:

Valvae anguste ellipticae vel anguste rhombicae, linearibus vel modice convexis marginibus, leniter vel non protractis late rotundatis apicibus. Longitudo: 9.6-17.0 μm, latitudo: 2.5-4.2 μm. Rhaphovalva concave, area axialis linearis, area centralis fere absens vel rotundata. Rhaphe recta filiformis poris centralibus et extremis terminalibus rectis. Striae transapicales radiantes omnino densiores ad apices, 30 in 10 μm vel to 35-40 in 10 μm ad apices. Striae 2-4 rotundatis vel transapicaliter elongatis areolis compositae. Areolae nonnunquam rimiformes ad marginem. Striae tantum rotundatis areolis compositae ad apices. Areovalva modice convexa, area axialis angusta linearis modice dilatata ad aream centralem. Area centralis modice elliptica. Striae transapicales radiantes omnino densiores ad apices 30 in 10 μm vel 35 in 10 μm ad apices. Striae 3-4 rotundatis vel transapicaliter elongatis areolis compositae. Areolae nonnunquam rimiformes ad marginem. Aperturae internae areolarum occlusae hymenibus. Areolae serei singularis ad limbum elongatae et nonnunquam late apertae.

HOLOTYPE (here designated): BR-4214 (National Botanic Garden, Meise, Belgium), microscopic slide and preserved sample.

ISOTYPES (here designated): BM-101456 (Natural History Museum, London, UK), ZU7/44 (HUSTEDT Collection, Bremerhaven, Germany), microscopic slides.

TYPE LOCALITY: Quinta das Quebradas, Caravelas stream (Ribeira das Caravelas), subregion Alto Trás-os-Montes (District: Bragança), in the Parque Natural do Douro Internacional, Portugal (coll. NOVAIS, coll. date 22/07/2007), coordinates 41º 13' 55.581'' N, 06º 45' 15.031'' W.

ETYMOLOGY: The specific epithet *caravelense* refers to the name of the stream “Caravelas” where the type material was sampled (Ribeira das Caravelas).

DESCRIPTION:

Valves narrowly elliptic or lanceolate to narrowly rhombic with linear to moderately convex margins and only very weakly to non-protracted, broadly rounded apices. Valve dimensions (n=120): 9.6-17.0 μm long and 2.5-4.2 μm wide. Raphe valve concave with a linear axial area and a central area varying from almost absent to rounded. Raphe straight, filiform with gradually expanding, straight central raphe pores and straight terminal endings. Transapical striae radiate throughout the entire valve, becoming denser and more strongly radiate towards the apices, 30 in 10 μm in the middle of the valve up to 35-40 in 10 μm near the apices. Striae composed of 2-4 rounded to transapically elongated areolae, sometimes being slit-like near the valve margin. Striae near the apices formed only by rounded areolae. Rapheless valve slightly convex with narrow, linear axial area slightly widening towards the central area. Central area weakly elliptical and almost absent, with more widely spaced striae bordering it. Transapical striae radiate throughout the whole valve, slightly denser near the apices, 30 in 10 μm up to 35 in 10 μm near the apices. Striae mainly composed of 3-4 round to transapically elongated areolae. Areolae terminating the striae near the valve margin sometimes slit-like. Internal areolae openings occluded by hymenes (Figure 4.15 ae). The areolae of the single row

along the mantle are elongated and are more or less widely open, which is a characteristic discernible under LM in girdle view (Figure 4.15 n-p).

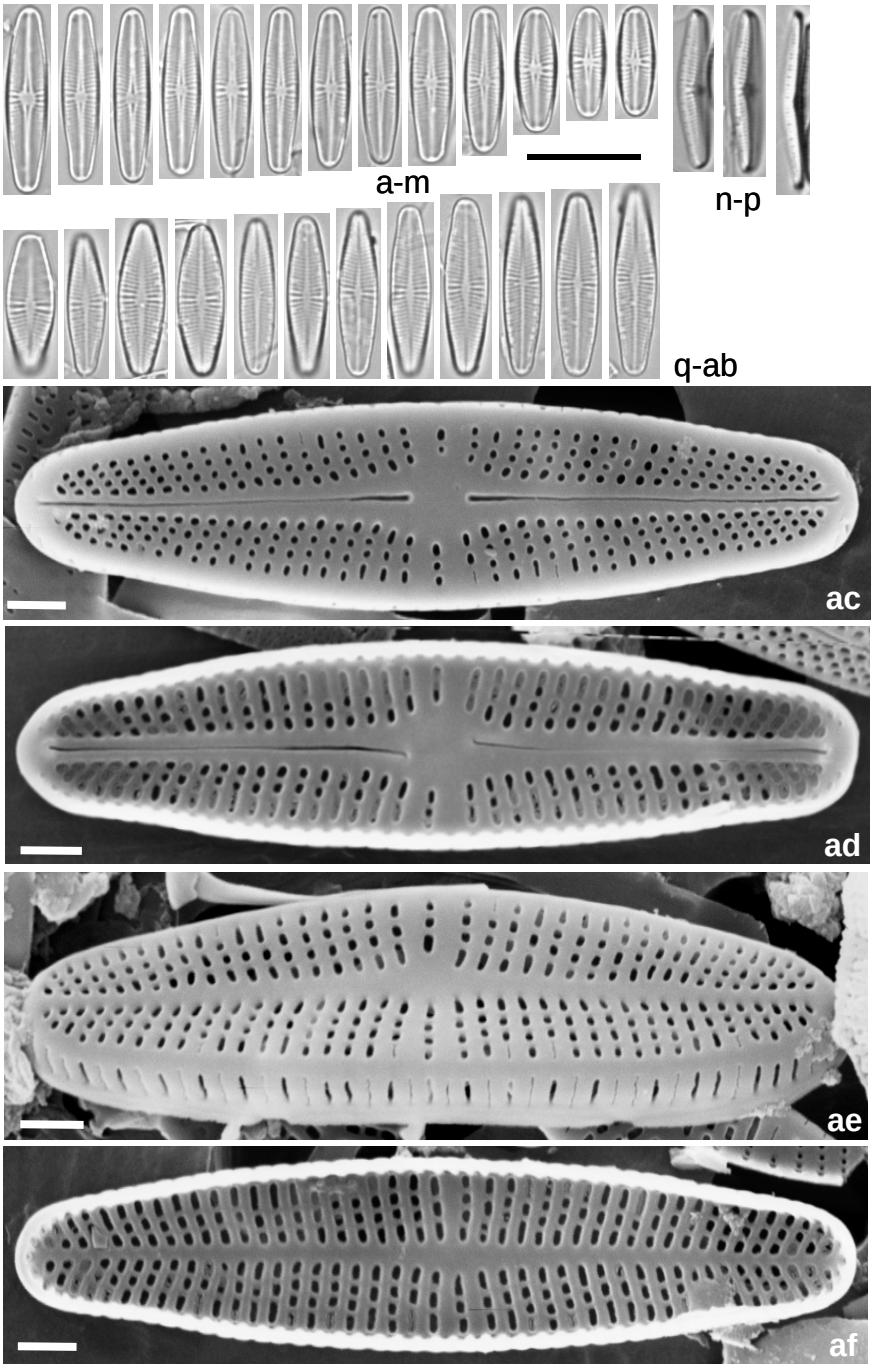

Figure 4.15 *Achnanthidium caravelense* Novais et Ector. Light and scanning electron micrographs of the type population from Caravelas stream (Portugal). (a-m). LM views of raphe valves. (n-p). LM views of raphe valves in girdle view. (q-ab). LM views of rapheless valves. (ac). SEM external view of a raphe valve. (ad). SEM internal view of a raphe valve. (ae). SEM external view of a rapheless valve. (af). SEM internal view of a rapheless valve.
Scale bar (a-ab) = 10 μm; scale bars (ac-af) = 1 μm.

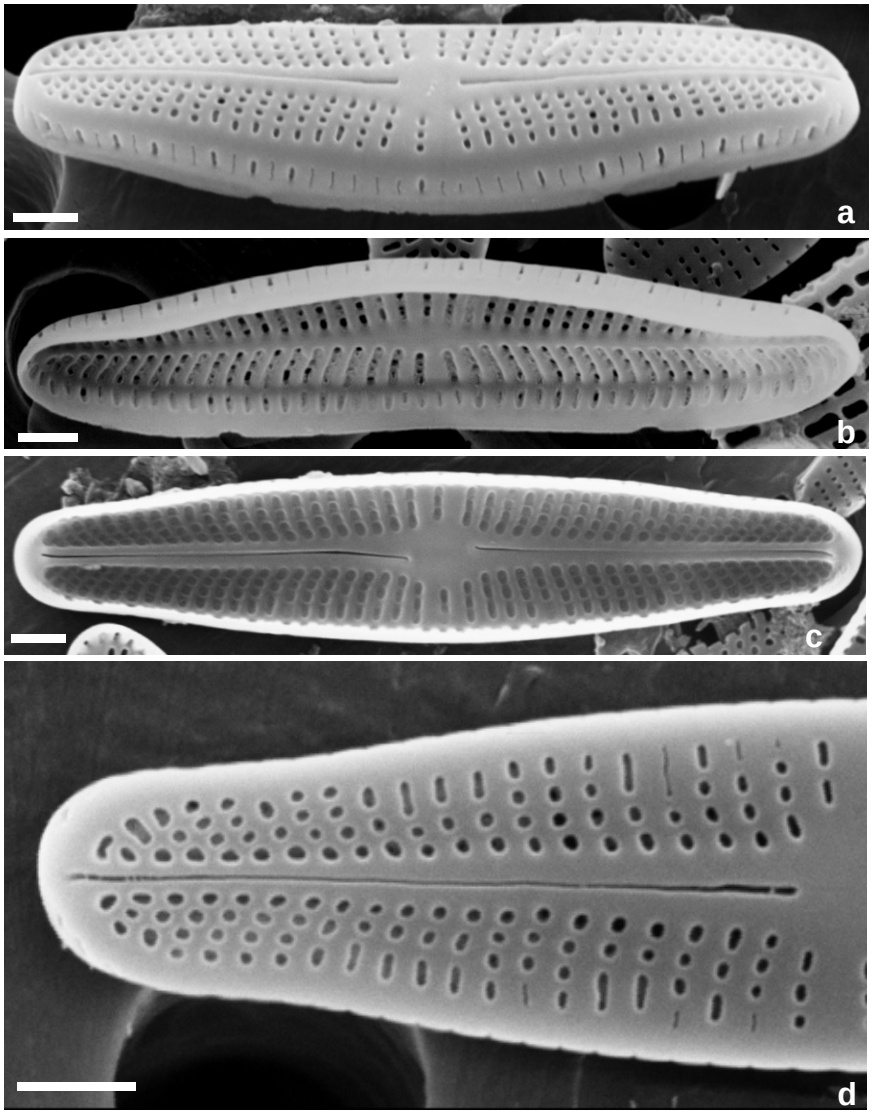

Figure 4.16 *Achnanthidium caravelense* Novais et Ector. Scanning electron micrographs of the type population from Caravelas stream (Portugal). (a) SEM external girdle view of a raphe valve showing the row of areolae more or less enlarged in the mantle. (b). SEM internal oblique view of a rapheless valve showing the row of areolae more or less enlarged in the mantle. (c). SEM internal valve view of a raphe valve showing the areolae covered by hymens. (d). SEM detail of the apical area of a raphe valve showing the slit-like areolae in the margins, in external view. Scale bars (a-d) = 1 μm.

COMPARISON WITH SIMILAR SPECIES:

Achnanthidium caravelense is one of the few species presenting an irregular appearance of the striae in girdle view, due to some enlarged areolae in the mantle. Among the few species presenting this characteristic we can find the African species *Achnanthes standeri* Cholnoky and *A. taiaensis* J. R. Carter & Denny, described from South Africa by CHOLNOKY (1957) and from Sierra Leone by CARTER & DENNY (1982), respectively. Nevertheless, *Achnanthidium caravelense* differs from *Achnanthes standeri* by the absence of the clearly visible irregularities in the rapheless valve in valve view (under LM), the more linear to linear-lanceolate rapheless valve in *A. standeri*, its bigger valve dimensions and the central area sometimes unilaterally expanded to the valve margin. *Achnanthes taiaensis* also presents clearly visible irregularities in the striae of the rapheless valve in valve view (under LM) and its striae are perpendicular to the midline, about 40 in 10 μm, whilst in *Achnanthidium caravelense* the striae are always radiant and circa 30 in 10 μm up to 35 in 10 μm close to the apices. *Achnanthes taiaensis* and *A. standeri* are two poorly known species, therefore they should be subject of detailed studies, since the original descriptions and drawings provided by CHOLNOKY (1957) and CARTER & DENNY (1982) correspond better to the current concept of the genus *Achnanthidium* and a future transfer to this genus should be considered.

The valves of *Achnanthidium caravelense* are usually wider than those of *A. minutissimum*, which presents both raphe and rapheless, linear-elliptic to linear-lanceolate valves with protracted capitate ends, while *A. caravelense* shows a narrowly rhombic rapheless valve and not protracted rounded ends. *Achnanthidium caravelense* can be easily distinguished from *A. affine* (Grunow) Czarn. by the absence of the typical central area presenting a large wedge-shaped fascia. *Achnanthidium exile* (Kütz.) Round et Bukht. differs from *A. caravelense* by its wider valves and the typical elliptic central area in the raphe valve.

To facilitate the comparison between *Achnanthidium caravelense* and similar species, their morphological characteristics are summarized in Table 4.4.

The species that *Achnanthidium caravelense* resembles most in terms of valve dimensions and outline is *A. eutrophilum*, which led us to compare the morphology and ultrastructure of *A. caravelense* (Figure 4.15 and Figure 4.16) with a typical population of *A. eutrophilum* from Portugal (Figure 4.17 and Figure 4.18). The Portuguese population of *A. eutrophilum* corresponds well to the characteristics of the epitype material (HLÚBIKOVÁ et al. 2011), just differing by its slightly narrower valves: 2.5-4.5 μm for the Portuguese population and 3.2-4.8 μm for the epitype material from the Main River in Germany, as can be seen in Table 4.4 where both populations are compared.

Table 4.4 Comparison between *Achnanthidium caravelense* and morphologically similar species.

Achnanthidium	***caravelense*** (Caravelas stream, this study)	***affine*** (KRAMMER & LANGE-BERTALOT 1991)	***eutrophilum*** (HLÚBIKOVÁ et al. 2011, Germany)	***eutrophilum*** (Monte Novo Reservoir, Portugal, this study)	***exile*** (KRAMMER & LANGE-BERTALOT 1991)	***minutissimum*** (KRAMMER & LANGE-BERTALOT 1991)	***standeri*** (CHOLNOKY 1957)	***taiaensis*** (CARTER & DENNY 1982)
Valve length (µm)	9.6-17	8-30	7.5-16	7-17	12-33	5-20 (25)	24-38	10-35
Valve width (µm)	2.5-4.2	3.5-5	3.2-4.8	2.5-4.5	4-6	(2.5) 3-3.5 (4)	4.5-5.5	3-5
Raphe valve								
Valve outline	narrowly elliptic	rhombic to rhombic-lanceolate	narrowly rhombic	rhombic to rhombic-elliptic	rhombic-lanceolate to linear-lanceolate	linear-elliptic to linear-lanceolate	linear to linear-lanceolate	lanceolate
Valve apices	broadly rounded; not protracted	acutely protracted	bluntly rounded to broadly cuneate	broadly rounded; not protracted to slightly protracted	bluntly rounded; not protracted to slightly protracted	protracted; capitate	protracted; rounded	rounded
Central area	rounded to elliptic	large wedge-shaped fascia	small rhombic, almost absent	very small or absent	elliptic	irregular; 1-2 shortened striae	small; sometimes only in one side	small oval
Striae (in 10 µm)	30	22-24	25-30 (27)	22-26	25-30	c. 30	28-30	36-40
Number of areolae per stria	2-4	3-5	4-6	3-5	-	3-4	-	-
Striation pattern	slightly radiate in the middle part, strongly radiate and slightly more densely spaced near the apices	slightly more densely spaced near apices	rounded to elongated areolae	radiate; slightly more densely spaced near the apices	radiate; more densely spaced near the apices	slightly more densely spaced near the apices	slightly radiate in the middle; strongly radiate near the apices	radiate
Areola morphology	rounded to elongated; often slit-like near the valve margin	areolae rounded near apices	slit-like or both slit-like and broadly elliptic in the mantle	rounded to slightly elongated; sometimes slit-like near the valve margin	-	areolae rounded	-	-

Achnanthidium	***caravelense*** (Caravelas stream, this study)	***affine*** (KRAMMER & LANGE-BERTALOT 1991)	***eutrophilum*** (HLÚBIKOVÁ et al. 2011, Germany)	***eutrophilum*** (Monte Novo Reservoir, Portugal, this study)	***exile*** (KRAMMER & LANGE-BERTALOT 1991)	***minutissimum*** (KRAMMER & LANGE-BERTALOT 1991)	***standeri*** (CHOLNOKY 1957)	***taiaensis*** (CARTER & DENNY 1982)
Rapheless valve								
Valve outline	narrowly rhombic	rhombic to rhombic-lanceolate	narrowly rhomboidal to lanceolate	rhombic	rhombic-lanceolate to linear-lanceolate	linear-elliptic to linear-lanceolate	linear to linear-lanceolate	lanceolate
Valve apices	obtusely rounded not protracted	acutely protracted	bluntly rounded to broadly cuneate	broadly rounded; not protracted to slightly protracted	bluntly rounded; not protracted to slightly protracted	protracted; capitate	protracted; rounded	rounded
Central area	elliptic	asymmetrical	narrowly rhomboidal to lanceolate, almost absent	very small or absent	elliptic	elliptic to lanceolate	undefined	small
Striae (in 10 µm)	30-32	22-24	25-30	22-26	25-30	c. 30	24-26	c. 40
Number of areolae per stria	3-4	3-4	4-6	4-6	-	3-5	-	-
Striation pattern	slightly radiate in the middle part, strongly radiate and slightly more densely spaced near the apices	equidistant throughout	rounded to elongated areolae	radiate; slightly more densely spaced near the apices	radiate; more densely spaced near the apices; more densely spaced in the middle than in the raphe valve	equidistant throughout	rougher than the striae of the raphe valve; short and thick shadow lines in the valve edges	perpendicular to the midline
Areola morphology	rounded to elongated; often slit-like near the valve margin	usually rounded areolae	slit-like or both slit-like and broadly elliptic in the mantle	rounded to slightly elongated	-	usually rounded areolae	-	-

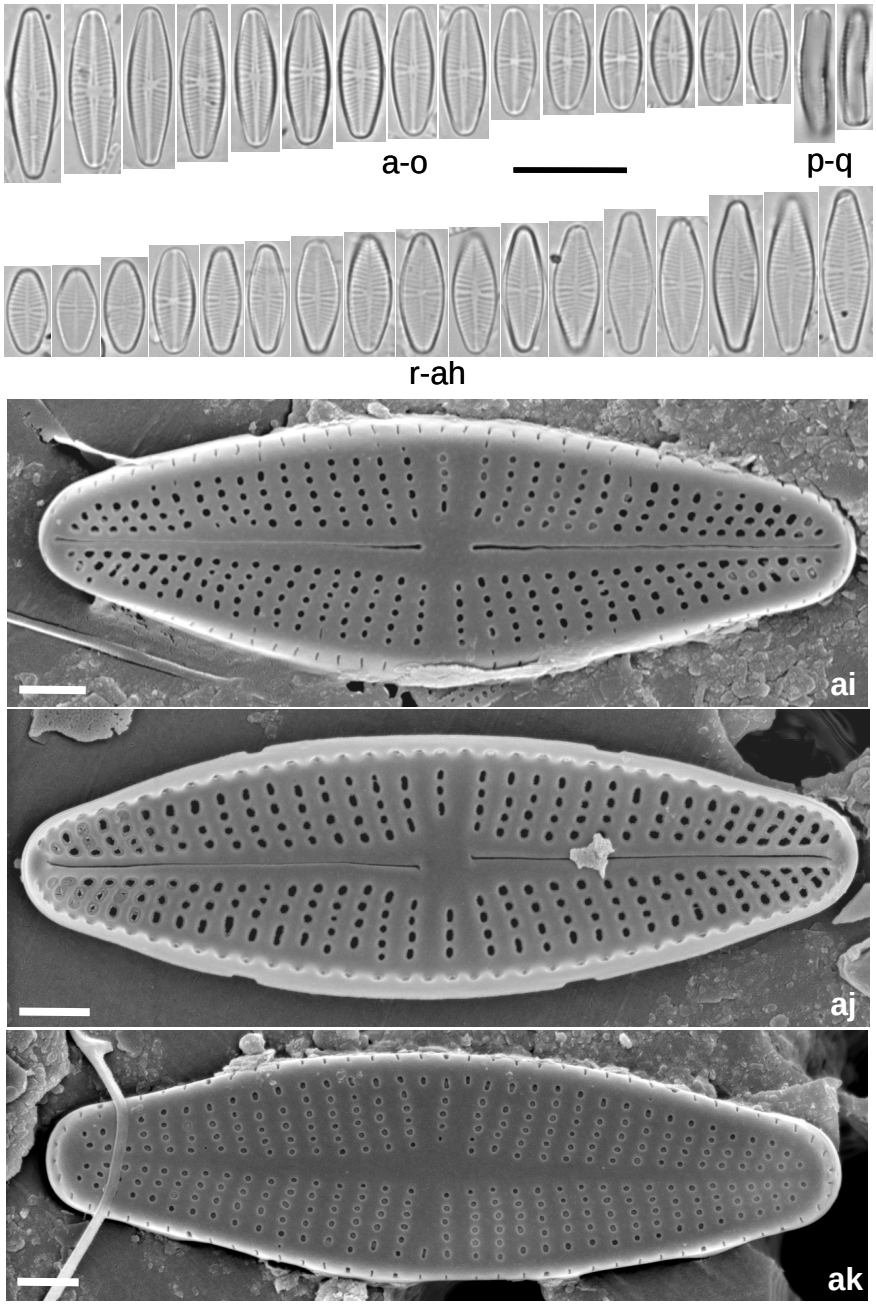

Figure 4.17 *Achnanthidium eutrophilum* (Lange-Bertalot) Lange-Bertalot. Light and scanning electron micrographs of the population from Monte Novo Reservoir (Portugal). (a-o) LM views of raphe valves. (p, q) LM views of frustules in girdle view. (r-ah) LM views of rapheless valves. (ai) SEM external view of a raphe valve. (aj) SEM internal view of a raphe valve. (ak) SEM external view of a rapheless valve. Scale bar (a-ah) = 10 μm; scale bars (ai-ak) = 1 μm.

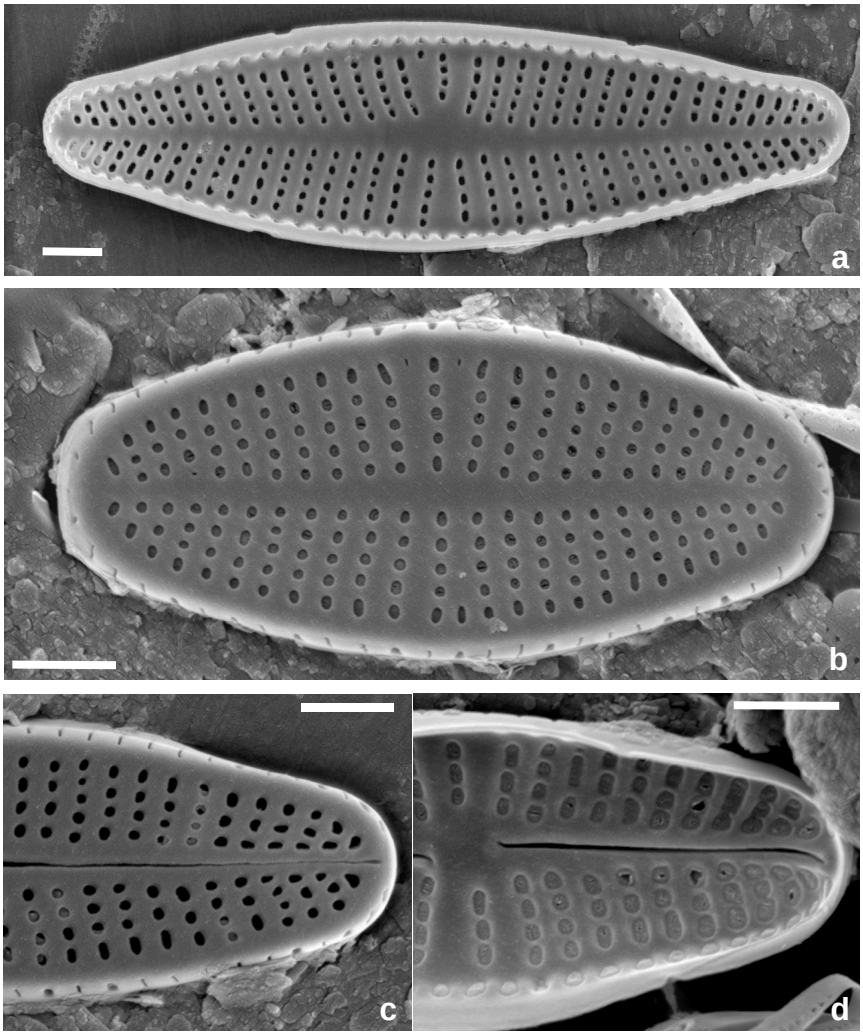

Figure 4.18 *Achnanthidium eutrophilum* (Lange-Bertalot) Lange-Bertalot. Scanning electron micrographs of the population from Monte Novo Reservoir (Portugal). (a) SEM internal view of a rapheless valve. (b) SEM external view of a rapheless valve showing the row of areolae more or less enlarged in the mantle. (c) SEM detail of the apical area of a raphe valve in external view. (d) SEM detail of the apical area of a raphe valve in internal view.
Scale bars (a-d) = 1 μm.

The observation of the LM micrographs showed that *Achnanthidium eutrophilum* presents a more rhombic raphe valve than *A. caravelense*; nevertheless, its rapheless valves are quite similar. Therefore, a morphometric analysis was performed in order to verify if there were measurable differences between these two species. A total of 120 valves (60 raphe valves and 60 rapheless valves) of each species have been measured and the results are given in Figure 4.19 and Figure 4.20. The morphometric analysis shows that there are differences between the two *Achnanthidium* species, mainly regarding the raphe valve, which is longer and narrower in *A. caravelense* than in *A. eutrophilum*, as seen in Figure 4.19. The rapheless valves are more similar, presenting more overlap among specimens, even though the majority of the *Achnanthidium caravelense* valves are larger, while the width is quite similar (Figure 4.20).

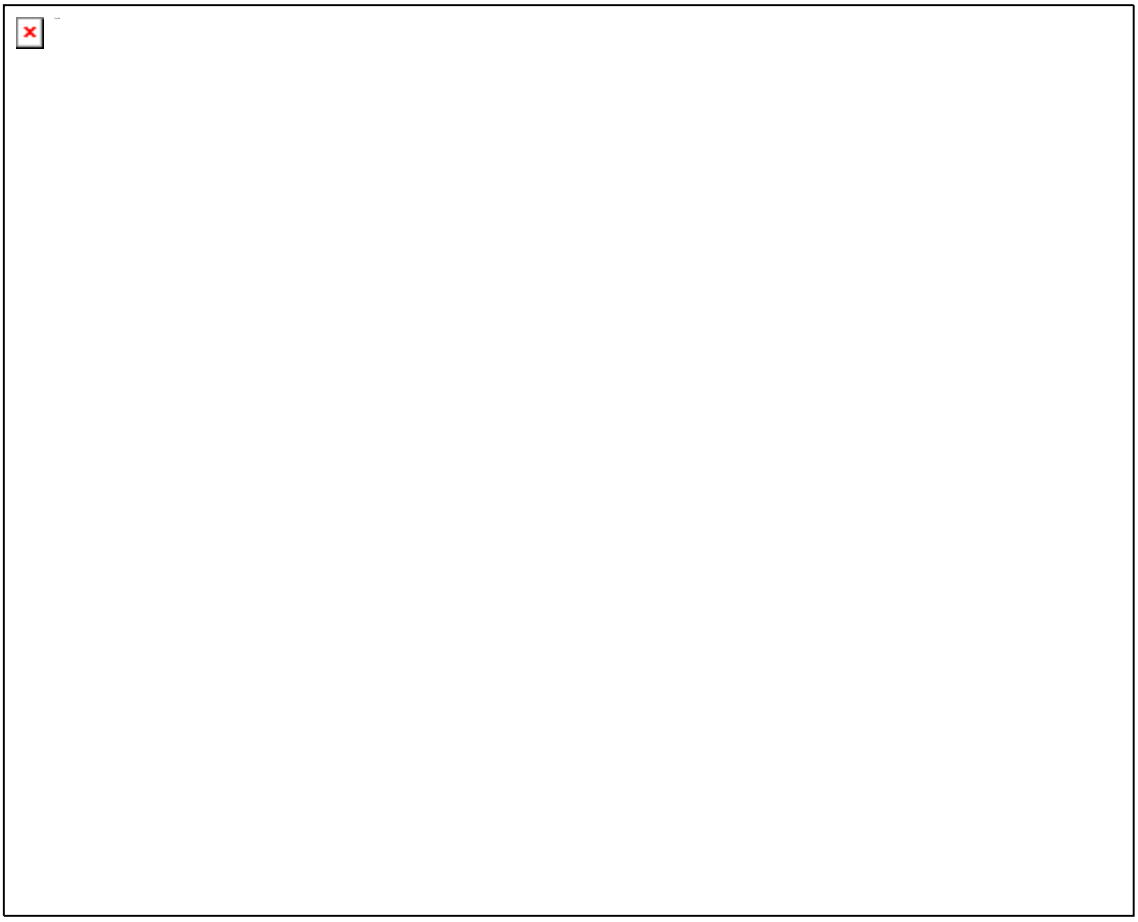

Figure 4.19 Dimensions of raphe valves of *Achnanthidium caravelense* (Caravelas stream) and *A. eutrophilum* (Monte Novo Reservoir) (n=120).

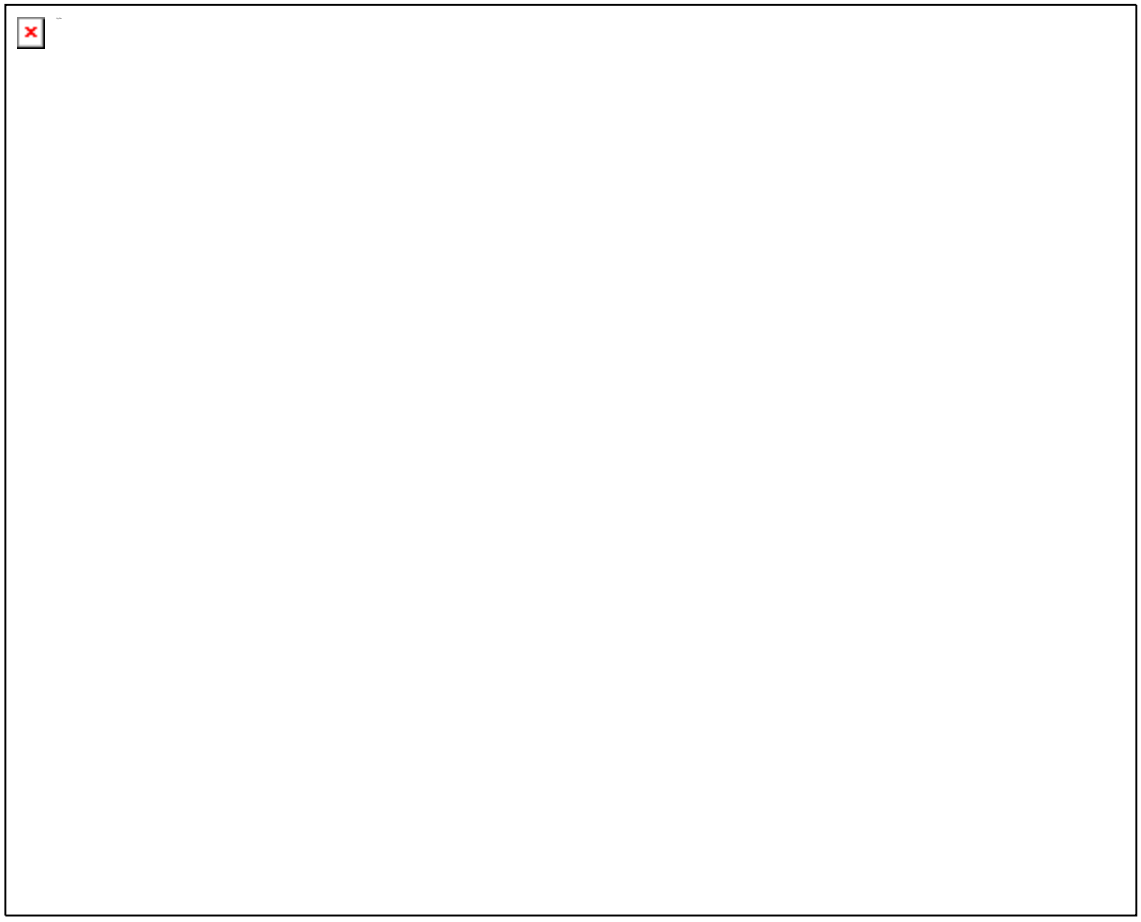

Figure 4.20 Dimensions of rapheless valves of *Achnanthidium caravelense* (Caravelas stream) and *A. eutrophilum* (Monte Novo Reservoir) (n=120).

The valve outline (especially of the raphe valve, seen in LM micrographs) and the morphometric analysis in terms of width and length demonstrated differences in both species. This led us to consider that the length/width ratio can be a good character to distinguish between them. The box-plots with the length/width ratio of *Achnanthidium caravelense* and *A. eutrophilum* (Figure 4.21) showed that it is indeed a good character to distinguish between them, especially in the case of the raphe valve. In addition, analysis of variance evidenced significant differences between the length/with ratio of *Achnanthidium caravelense* and *A. eutrophilum* with $p<0.001$. *Achnanthidium caravelense* presents a length/width ratio usually above 4 while in *A. eutrophilum* it is around 3, as seen in Table 4.5 where the main morphometric characteristics of both species are summarized.

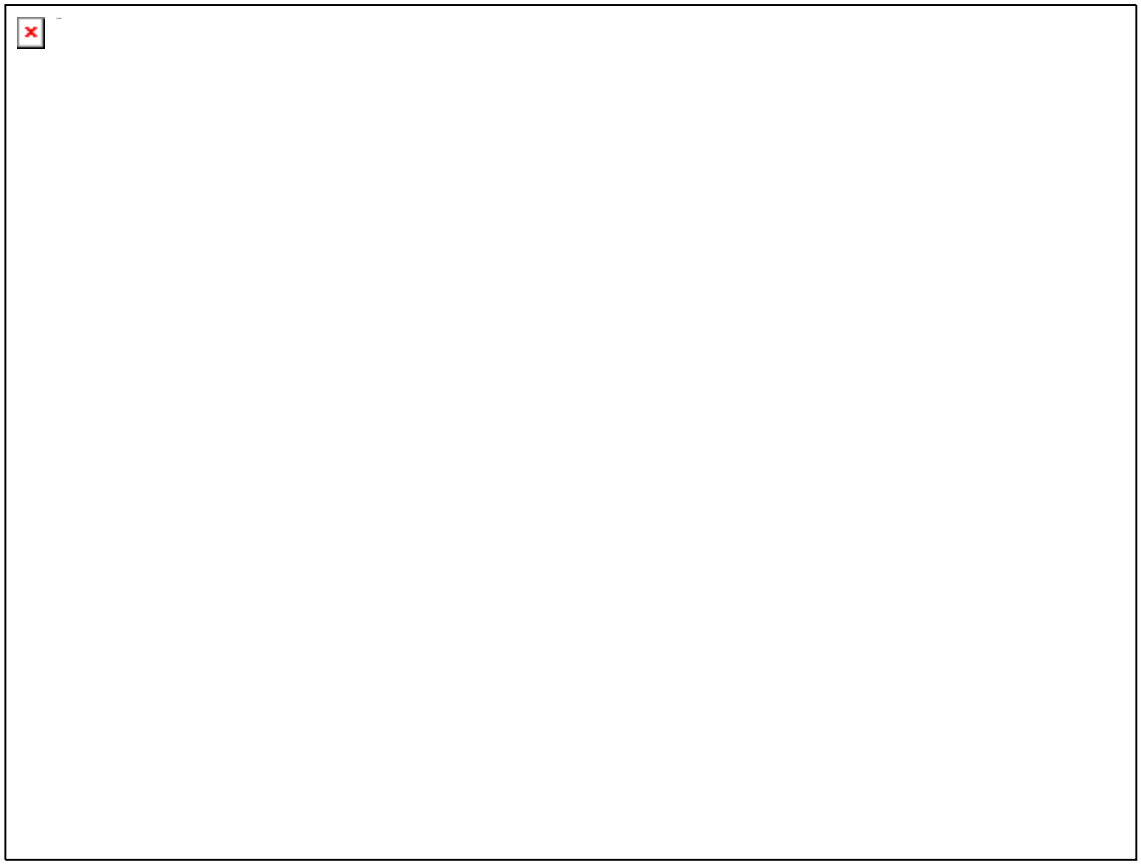

Figure 4.21 Length/width ratio of raphe (R+) and rapheless valves (R-) of *Achnanthidium caravelense* (Caravelas stream) and *A. eutrophilum* (Monte Novo Reservoir) (n=240).

Table 4.5 Morphometric comparison between *Achnanthidium caravelense* (Caravelas stream) and *A. eutrophilum* (Monte Novo Reservoir, Portugal). Minimum, maximum and median values are presented (n=240).

	A. caravelense		*A. eutrophilum*	
	Rapheless valve	Raphe valve	Rapheless valve	Raphe valve
Length (µm)	11.0-17.0 (14.5)	9.6-16.4 (14.7)	7.0-15.5 (10.7)	7.0-17.0 (12.0)
Width (µm)	3.0-4.2 (3.5)	2.5-4.0 (3.1)	2.5-4.5 (4.0)	3.0-4.5 (4.0)
Ratio (length/width)	2.8-5.0 (4.1)	3.1-5.4 (4.6)	2.0-4.0 (2.9)	2.3-4.3 (3.1)

ECOLOGY, DISTRIBUTION AND ASSOCIATED DIATOM FLORA:

Although the morphology of *Achnanthidium caravelense* under LM could resemble *A. eutrophilum* at first sight, the fact that it was found in samples from several reference sites, according to the classification in the context of the implementation of the Water Framework Directive (2000/60/EC) in Portugal, made us consider it could be a species with different ecological requirements. Subsequently, the abundance-weighted averages of 16 physical and chemical variables and current velocity, altitude, distance from source and catchment area were calculated for both species in Portugal (Table 4.6).

Table 4.6 Abundance-weighted averages (WA), minimum (min) and maximum (max) of 16 physical and chemical variables and current velocity, altitude, distance from source and catchment's area corresponding to the ecological spectrum of the presence of *Achnanthidium caravelense* and *A. eutrophilum* in Portugal. Asterisks represent the parameters that were significantly different for both species with $p<0.001$** and $p<0.05$*.

	A. caravelense				***A. eutrophilum***			
	WA	**min**	**max**	**n**	**WA**	**min**	**max**	**n**
$N\text{-}NH_4^+$ (µg N L^{-1})	**36**	1	320	28	**71**	1	670	43
Cl^- (mg Cl^- L^{-1}) **	**11.2**	3.0	85.0	31	**20.9**	4.0	92.8	30
TOC (mg C L^{-1}) **	**2.0**	1.2	4.2	31	**3.8**	0.7	18.8	29
Total hardness (mg $CaCO_3$ L^{-1}) **	**19.1**	5.0	44.0	31	**90.1**	0.1	268.0	43
$P\text{-}PO_4^{3-}$ (µg P L^{-1}) **	**6**	1	21	24	**78**	1	900	40
Total phosphorus (µg P L^{-1})	**9**	1	51	27	**144**	1	1120	43
Soluble reactive phosphorus (SRP) (µg P L^{-1}) **	**2**	1	7	22	**13**	1	44	26
$N\text{-}NO_3^-$ (µg N L^{-1}) **	**1707**	2	4210	30	**2470**	150	7600	43
$N\text{-}NO_2^-$ (µg N L^{-1}) **	**21**	1	290	29	**71**	1	220	38
Na^+ (mg Na^+ L^{-1}) **	**8.3**	0.4	39.3	31	**5.5**	0.7	15.8	30
SO_4^{2-} (mg SO_4^{2-} L^{-1})	**4.4**	0.1	20.1	31	**29.5**	2.2	170.6	29
Ca^{2+} (mg Ca^{2+} L^{-1}) **	**4.9**	2.0	15.0	31	**19.8**	2.0	110.6	30
DO (% sat.)	**90**	76	100	31	**85**	66	119	30
DO (mg L^{-1}) *	**8.2**	6.2	9.1	31	**9.4**	5.2	12.8	43
pH	**7.1**	6.2	8.1	31	**8.1**	6.4	9.0	43
Conductivity (µS cm^{-1}) *	**76**	28	307	31	**263**	35	723	43
Current velocity (m s^{-1})	**0.5**	0.0	1.3	31	**0.7**	0.0	1.9	29
Altitude (m) **	**196**	5	898	31	**78**	13	545	30
Catchment area (km^2)	**1103**	13	15491	31	**7171**	19	122704	30
Distance from source (m)	**38911**	29	129546	31	**83974**	103	968460	30

Analysis of the variables weighted averages and their ranges, presented in Table 3, supports the hypothesis that both species differ by their ecological preferences. The results from a multivariate analysis (Hotelling's Trace statistics) confirm the difference (p<0.001). In Table 3 are marked the variables for which the two species showed statistically significant different preferences. Therefore, the ecological preferences of these species are significantly different (with p<0.001) for chlorides, total organic carbon, total hardness, phosphates, soluble reactive phosphorus, nitrates, nitrites, sodium, calcium and altitude. In addition, their ecological preferences are different (with p<0.05) for conductivity and dissolved oxygen. No significant differences were detected for ammonia, total phosphorus, sulphates, catchment area, distance from source, current velocity, pH and dissolved oxygen (% saturation).

Both *Achnanthidium* species never occurred in the same samples at times. *Achnanthidium caravelense* occurs in circumneutral waters (WA pH: 7.1), with low conductivity (WA cond.: 76 μS cm^{-1}) while in Portugal *A. eutrophilum* prefers slightly alkaline waters (WA pH: 8.1) with moderate conductivity (WA cond.: 263 μS cm^{-1}). Furthermore, the range of nutrient concentrations is more ample for *Achnanthidium eutrophilum*: WA N-NO_3^-: 1707 μg L^{-1} (*A. caravelense*) - 2470 μg L^{-1} (*A. eutrophilum*); WA N-NO_2^-: 21 μg L^{-1} (*A. caravelense*) – 71 μg L^{-1} (*A. eutrophilum*), as well as the soluble reactive phosphorus: WA SRP: 2 μg L^{-1} (*A. caravelense*) - 13 μg L^{-1} (*A. eutrophilum*). Furthermore, the analysis proves that both species may occur in similar river types but with different degrees of organic contamination.

The ecological preferences of *Achnanthidium eutrophilum* in Portuguese rivers are in accordance with the information provided by LANGE-BERTALOT & METZELTIN (1996) who stated that this species occurs in oligotrophic to polytrophic waters and by PONADER & POTAPOVA (2007), who referred that in the Appalachian rivers (United States of America) this species was found in four sites characterized by pH between 8.1-8.3, conductivity between 291-583 μS cm^{-1} and a wide range of nutrient concentrations (NO_3^- + NO_2^-: 700-2200 μg L^{-1}). Regarding phosphate, *Achnanthidium eutrophilum* was found in the United States of America in sites with a lower range of values (PO_4^{3-}: 10-26 μg L^{-1}) than the Portuguese populations (WA PO_4^{3-}: 78 μg L^{-1}).

In total, *Achnanthidium caravelense* has been recorded with abundance above 1 % in 31 sampling sites (30 in the North, only one in the Centre, and none in the South of Portugal) belonging to the Ave, Cávado, Douro, Lima, Leça and Minho watersheds. The characterization of the sampling sites and the respective distribution map are presented in Table 4 and Figure 81. *Achnanthidium eutrophilum* has been recorded in abundance above 1 % in 43 sampling sites in streams and reservoirs distributed all over the country and belonging to the watersheds of Ribeiras do Algarve (5 sites), Mira (1 site), Guadiana (6 sites), Tejo (16 sites), Mondego (5 sites), Vouga (4 sites) and Douro (6 sites).

Besides *Achnanthidium caravelense*, the diatom community was dominated in its type locality by *A. lineare* W. SM. and *A. rivulare* POTAPOVA et PONADER, which are species characteristic of nutrient-poor to moderately nitrogen rich waters (POTAPOVA & PONADER 2004, VAN DE VIJVER et al. 2011a). *Achnanthidium rivulare* is a species characteristic of soft waters and a pH of approximately 6

(POTAPOVA & PONADER 2004), while *A. lineare* is characteristic of circumneutral to weakly alkaline waters (pH 7.0-8.5) and very low to moderate specific conductivity, between 23-200 µS cm^{-1} (VAN DE VIJVER et al. 2011a).

4.3.4 Conclusion

The new species *Achnanthidium caravelense* clearly belongs to the genus *Achnanthidium*, according to the description of ROUND & BUKHTIYAROVA (1996), on the basis of the valve outline, radiate striae, uniseriate (in SEM) and wider spaced striae in the centre of the valve. In girdle view cells are shallow-V-shaped. The raphe valve has a straight central raphe hardly expanding at the centre and a row of elongated areolae in the mantle.

Within the genus *Achnanthidium* this species belongs to the complex around *A. minutissimum*, due to its straight terminal raphe fissures, in opposition to the species with terminal raphe fissures clearly deflected, such as *A. convergens* (H. KOBAYASI) H. KOBAYASI, *A. japonicum* (H. KOBAYASI) H. KOBAYASI, *A. latecephalum* H. KOBAYASI, *A. pyrenaicum* (HUST.) H. KOBAYASI (KOBAYASI 1997), *A. deflexum* (REIMER) J. C. KINGSTON, *A. rivulare* POTAPOVA et PONADER 2004 (POTAPOVA & PONADER 2004) and *A. zhakovschikovii* POTAPOVA (POTAPOVA 2006).

Achnanthidium caravelense is characterized by a set of distinct morphological and ecological features that separate it well from all other similar *Achnanthidium* species and it is widely distributed in Portuguese rivers. There is therefore a rather high probability that this species also occurs commonly in other European regions, in rivers with suitable conditions and has not yet been recorded due to probable misidentifications with *Achnanthidium eutrophilum* or *A. minutissimum*.

Table 4.7 Characteristics of sampling sites. Coordinates referred to the datum Lisboa. The identification number (ID) refers to the identification of the sites presented in the distribution map.

Site	Watercourse (Basin)	Sampling date	Latitude	Longitude	ID
Além da Veiga	Ave River (Ave)	25/09/2007	41º 32' 11.089" N	08º 15' 48.312" W	12
Alto Cávado	Cávado River (Cávado)	24/09/2007	41º 48' 43.800" N	07º 51' 41.200" W	13
Arcos de Valdevez	Vez River (Lima)	21/09/2007	41º 49' 54.300" N	08º 24' 57.800" W	14
Barral	Homem River (Cávado)	26/09/2007	41º 40' 15.787" N	08º 22' 58.694" W	15
Cantim	Leça River (Leça)	16/09/2007	41º 16' 13.790" N	08º 28' 08.375" W	16
Cavacadouro	Homem River (Cávado)	26/09/2007	41º 43' 07.787" N	08º 18' 08.708" W	17
Cidadelhe	Lima River (Lima)	27/09/2007	41º 51' 34.687" N	08º 15' 32.467" W	18
Férrea	Peneda River (Lima)	20/09/2007	41º 57' 41.166" N	08º 13' 33.703" W	19
Froufe	Froufe River (Lima)	27/09/2007	41º 49' 15.387" N	08º 17' 04.012" W	20
Lanheses	Lima River (Lima)	21/09/2007	41º 43' 39.800" N	08º 40' 14.500" W	21
Monção	Minho River (Minho)	20/09/2007	42º 04' 49.800" N	08º 29' 35.600" W	22
Monte Branco	Neiva River (Lima)	22/09/2007	41º 36' 58.886" N	08º 44' 37.633" W	23
Parada de Bouro	Cávado River (Cávado)	26/09/2007	41º 38' 53.788" N	08º 14' 54.716" W	24
Ponte na E.N. 103	Rabagão River (Cávado)	24/09/2007	41º 43' 33.590" N	07º 52' 21.180" W	26
Pontilhões	Ave River (Ave)	22/09/2007	41º 27' 02.800" N	08º 20' 54.000" W	25
Quinta das Quebradas	Caravelas Stream (Douro)	22-07-2007	41º 13' 55.581" N	06º 45' 15.031" W	1
Rabaçal	Rabaçal River (Douro)	14/08/2007	41º 31' 18.013" N	07º 13' 49.497" W	2
Sabor	Sabor River (Douro)	10/08/2007	41º 53' 10.695" N	06º 43' 57.239" W	4
Segude	Mouro River (Minho)	20/09/2007	42º 02' 44.394" N	08º 23' 15.807" W	27
Sequeirós	Homem River (Cávado)	26/09/2007	41º 44' 19.500" N	08º 16' 13.400" W	28
Sub-Igreja	Vez River (Lima)	21/09/2007	41º 55' 04.285" N	08º 26' 34.386" W	29
Tâmega 1	Tâmega River (Douro)	24/09/2007	41º 32' 25.909" N	07º 47' 09.085" W	5
Tâmega 2	Tâmega River (Douro)	24/09/2007	41º 29' 12.991" N	07º 54' 12.934" W	7
Troporiz	Gadanha River (Minho)	20/09/2007	42º 03' 27.704" N	08º 31' 28.094" W	30
Tua	Tua River (Douro)	16/08/2007	41º 23' 12.765" N	07º 12' 03.892" W	8
Tuela 1	Tuela River (Douro)	14/08/2007	41º 40' 12.568" N	07º 08' 27.694" W	10
Tuela 2	Tuela River (Douro)	11/08/2007	41º 34' 12.526" N	07º 09' 58.814" W	9
Uima	Uima Stream (Douro)	14/08/2007	41º 00' 44.018" N	08º 30' 11.363" W	11
Vale Armeiro	Rabaçal River (Douro)	10/08/2007	41º 46' 09.905" N	07° 09' 46.586" W	3
Veral	Tâmega River (Douro)	21/07/2007	41º 33' 45.071" N	07º 44' 30.135" W	6
Vilela	Pequeno River (Ave)	25/09/2007	41º 32' 51.100" N	08º 15' 17.400" W	31

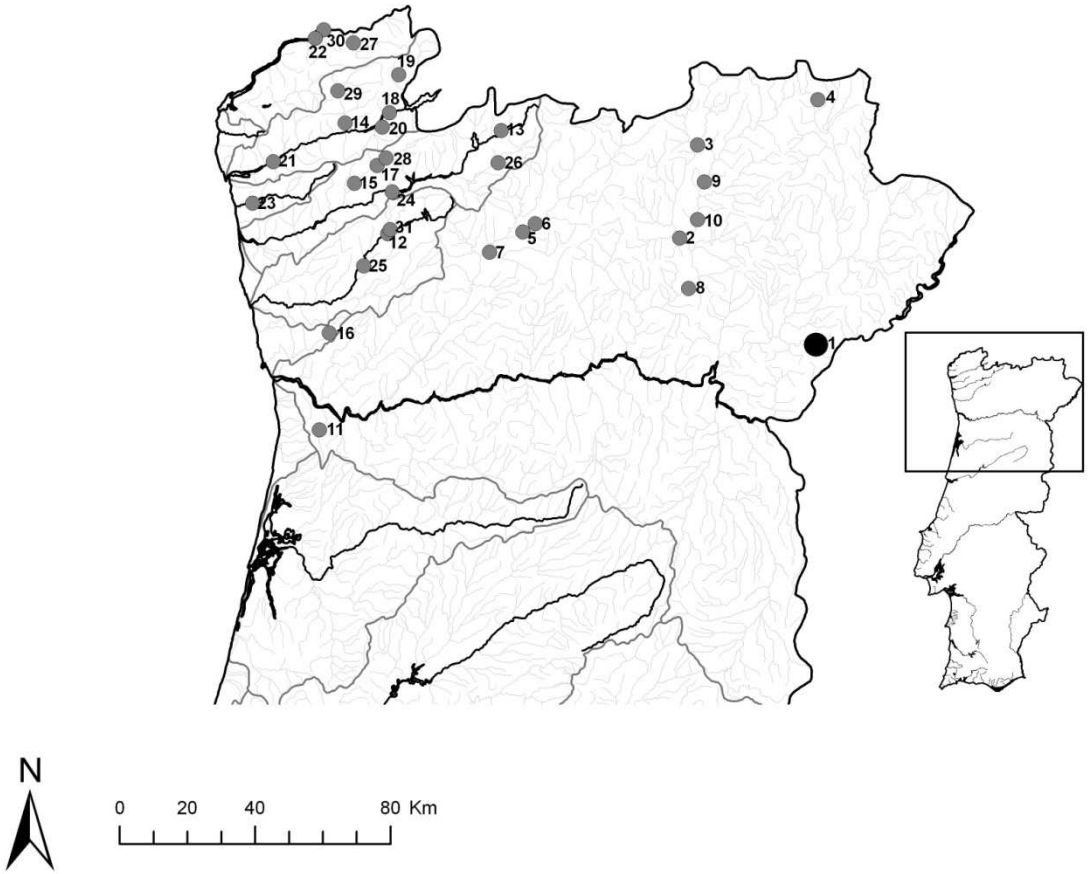

Figure 4.22 Distribution map of *Achnanthidium caravelense* in the North and Centre of Portugal. The black circle represents the type locality. The numbers correspond to the identification number (ID) presented in Table 4.

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Chapter 5

ECOLOGICAL ASSESSMENT OF PORTUGUESE RESERVOIRS BASED ON LITTORAL EPILITHIC DIATOMS

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5 Ecological assessment of Portuguese reservoirs based on littoral epilithic diatoms

Abstract

For the implementation of the Water Framework Directive (2000/60/EC) in Portugal, the Portuguese Water Institute (INAG) classified reservoirs in three hydromorphological types and two ecological conditions (reference or non-reference). Subsequently, this study has been performed with the aim to use littoral epilithic diatoms to validate the established typology for Portugal and to analyse the ability of littoral epilithic diatoms to discriminate between reference and non-reference conditions of the reservoirs. The statistical analysis performed (PCA, DCA, ANOSIM and SIMPER), based on the study of the eighteen reservoirs allowed the following results: i) the diatom communities allowed the separation of all the a priori defined types (North, Main Courses, South); ii) there were no significant differences between the diatom communities of the reservoirs previously classified as presenting reference and non-reference ecological conditions; iii) the classification of the reservoirs as presenting reference or non-reference conditions based on the use of the diatom Specific Pollution sensitivity Index as a complementary variable allowed the classification of Vilarinho das Furnas, Meimoa and Santa Luzia as the Maximum Ecological Potential reservoirs for the hydromorphological type North, of Odeleite as the Maximum Ecological Potential reservoir for the type South and the lack of Maximum Ecological Potential reservoirs for the type Main Courses. This study confirms that the biological methods based on the use of epilithic littoral diatoms can provide a good contribution to the other biological elements for the whole assessment of the ecological potential of aquatic lentic systems in Portugal, almost exclusively constituted by reservoirs.

Keywords: Epilithon · Heavily Modified Water Bodies · Littoral diatoms · Portugal · Water Framework Directive.

5.1 Introduction

Diatoms have been widely used to assess the ecological status in European rivers (KELLY & WHITTON, 1995; PRYGIEL & COSTE 1999; KELLY et al. 2008). In Portugal, several studies using diatoms as water quality indicators in rivers have also been performed, mainly in the central region of the country (ALMEIDA 2001; ALMEIDA & GIL 2001; NUNES et al. 2003; FEIO et al. 2007). However, studies on the use of littoral diatoms for water quality monitoring in lentic environments are scarce due to the great microhabitat variability found in these communities (SCHÖNFELDER et al. 2002). Therefore, the estimation of the trophic status in these ecosystems is usually based on (i) annual averages of total phosphorus or chlorophyll a concentration, (ii) long-term observations of phytoplankton or (iii) diatom remains in deep sediment samples (HALL & SMOL 1999). According to POULÍČKOVÁ et al. (2004), the advantage of using littoral diatoms in lakes is most evident for specific sites rather than for the whole lake, which can be more easily assessed by phytoplankton analysis. Nevertheless, mainly due to the implementation of the Water Framework Directive (WFD, THE EUROPEAN PARLIAMENT & EUROPEAN COUNCIL 2000) in the member states of the European Union, there has been an increased interest in the use of periphytic communities for the assessment of the ecological quality of lacustrine habitats (HOFMANN 1994; KING et al. 2002a, b; DENICOLA et al. 2004; ŠTEFKOVÁ 2006).

The WFD represents a modification in the way water bodies are managed, with the concept of "ecological status" replacing previous ones, as concentration of particular pollutants or needs of end-users. According to the WFD, the ecological status of a water body should be defined relative to the deviation of its species composition and abundance from the reference condition, i.e. the expected ecological quality in the absence of anthropogenic influence (SCHAUMBURG et al. 2004; ECTOR & RIMET 2005). Among the biological methods established by Annex V of the WFD for the definition of ecological quality in rivers and lakes, methods to assess phytobenthos tend to focus on diatoms because they form a large part of the freshwater algal diversity (KING et al. 2000). The use of diatoms as proxies for phytobenthos has been additionally supported by the results obtained by KELLY et al. (2008), based on the analysis of the dataset compiled with littoral samples from standing waters in the English Lake District and compared with several limnological variables using transfer functions generated from diatoms and non-diatoms, separately and combined.

In Mainland Portugal, almost all freshwater lentic water bodies are reservoirs, except for the lakes of glacial origin located in Serra da Estrela (BOAVIDA & GLIWICZ 1996). These reservoirs are relatively recent and generally associated to anthropogenic uses (CABECINHA et al. 2009a). Up to date, limnological studies of Portuguese reservoirs have generally focused on phytoplankton (e.g. CABEÇADAS & BROGUEIRA 1987; CRAVEIRO & SANTOS 1997; GERALDES & BOAVIDA 2005) and have not considered littoral diatoms. Recently, CABECINHA et al. (2009a, b) have used a multi-scale approach for the definition of reservoirs' ecological potential, though the biological parameters consisted uniquely in chlorophyll a and phytoplankton analysis. According to FERREIRA et al. (2009), this poor knowledge about the biological communities of Portuguese reservoirs can be related to the late interest in limnology by the Portuguese scientists and universities and also to the need of multidisciplinary teams.

The present work is integrated in the cooperation and research protocol “Ecological quality and integrated management of reservoirs”, which is a large project led by the Portuguese Water Institute (INAG) that aims i) to validate the pre-established typology of Portuguese reservoirs by means of littoral epilithic diatoms, and ii) to analyse the ability of littoral epilithic diatoms to discriminate between reference and non-reference ecological conditions of reservoirs.

5.2 Methods

5.2.1 Study area

Portuguese reservoirs have previously been classified by the INAG within this project in (a) three hydromorphological types (North, Main Courses, South), based on the application of the system B of the WFD and including 23 mandatory, facultative and specific variables (FERREIRA et al. 2009), and (b) two ecological conditions (reference, non-reference) according to several criteria, presented in FERREIRA et al. (2009), i.e. land-use in the watershed and in the surroundings of the reservoir, specifically the percentage of the basin occupied by intensive or extensive agriculture and urbanization; pressure by biodegradable substances evaluated by the urban and industrial BOD_5 loads and by the presence of topic pollution sources such as farms or urban effluents; non biodegradable pollutants such as heavy metals, evaluated by the presence of industries, mining activities or car garages in the basin; urban and leisure pressure in the margins and in the reservoirs, such as beaches, nautical sports or fishing areas; the presence and intensity of recreational fishing; changes in the water level, determined by the reservoir use. It is noteworthy that at this stage neither measurable physico-chemical parameters nor biological elements were taken into account.

For this study, eighteen reservoirs distributed throughout the whole Portuguese territory have been considered: six reservoirs have been selected within each hydromorphological type, three reference and three non-reference conditions reservoirs. The eighteen reservoirs belong to five catchments (Fig. 1): Cávado (1 reservoir), Douro (6 reservoirs), Tejo (7 reservoirs), Guadiana (3 reservoirs) and Mira (1 reservoir). The majority of the reservoirs have hydroelectric power production as their main purpose, although some secondary uses are also frequent, such as irrigation and water supply. The studied reservoirs presented a wide range of morphometric characteristics, with a total volume of water ranging from 10-485 hm3 and depth between 18-94 m (Table 5.1). Their morphometric characterization and INAG pre-classification in terms of ecological condition and hydromorphological types are presented in Table 5.1 and in Figure 5.1.

Table 5.1 Morphometric characterization and INAG classification of the studied reservoirs in terms of hydromorphological types, presence of perceptible flow, ecological condition and SPI scores.

Reservoir name	Watershed	Year of construction	Volume (Hm^3)	Depth (m)	Hydromorphological type	Perceptible flow	Ecological condition	SPI
1 - V. Furnas	Cávado	1972	118	94	North	No	Reference	19.7
2 - Meimoa	Tejo	1985	41	50	North	No	Reference	18.1
3 - Santa Luzia	Tejo	1942	54	76	North	No	Reference	17.4
4 - Marateca	Tejo	1991	37	25	North	No	Non-reference	15.1
5 - Torrão	Douro	1988	124	69	North	No	Non-reference	13.5
6 - Varosa	Douro	1976	13	76	North	No	Non-reference	14.3
7 - Belver	Tejo	1952	13	30	Main Courses	Yes	Reference	13.8
8 - Valeira	Douro	1976	97	48	Main Courses	Yes	Reference	13.0
9 - Pocinho	Douro	1982	81	49	Main Courses	Yes	Reference	13.8
10 - Fratel	Tejo	1973	93	43	Main Courses	Yes	Non-reference	9.6
11 - Régua	Douro	1973	95	41	Main Courses	Yes	Non-reference	14.9
12 - Crestuma	Douro	1985	106	65	Main Courses	Yes	Non-reference	12.5
13 - Odeleite	Guadiana	1997	132	50	South	No	Reference	18.9
14 - Santa Clara	Mira	1968	485	83	South	No	Reference	16.2
15 - T. Grande	Guadiana	1984	10	18	South	No	Reference	14.4
16 - Monte Novo	Guadiana	1982	15	30	South	No	Non-reference	11.7
17 - Montargil	Tejo	1958	180	36	South	No	Non-reference	16.7
18 - Maranhão	Tejo	1957	220	49	South	No	Non-reference	10.0

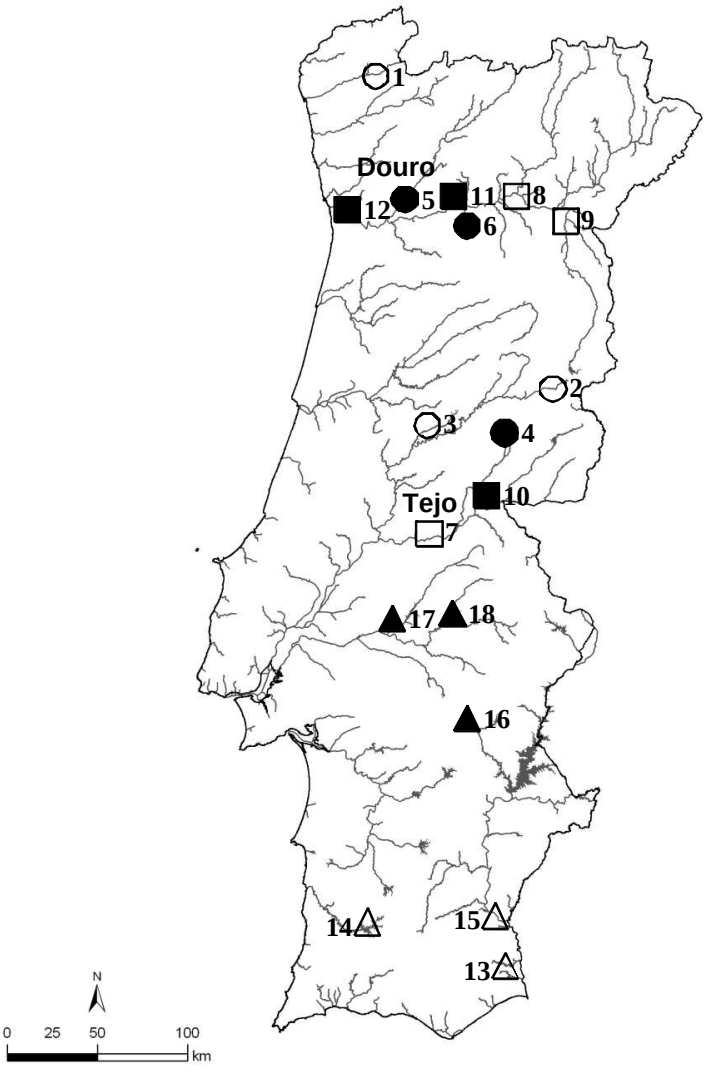

Figure 5.1 Location of the Portuguese reservoirs studied. White circle: North reference. Black circle: North non-reference. White square: Main Courses reference. Black square: Main Courses non-reference. White triangle: South reference. Black triangle: South non-reference.

5.2.2 Sampling and laboratory techniques

Epilithic littoral diatoms were seasonally collected in 2006 (between February and November) from stones in the margins (located approximately 500 m far from the dam), of the eighteen reservoirs following the European norms for sampling in lakes (KING et al. 2006). Special attention was paid to avoid the placement of sampling points near stream mouths. In all studies it is important to ensure that the uncertainty introduced by the sampling process is reduced. Therefore, in the present study all the sampling was performed on stones by the same researcher team and in the same site of the reservoir in each season.

Water samples for phytoplanktonic chlorophyll a (Chl a) determination and chemical analyses were simultaneously collected along with diatom samples, from the water column, in the middle of the reservoir and approximately 500 m far from the dam. These samples were kept cool and in the dark until laboratory processing. Some environmental parameters, such as temperature, pH, concentration of dissolved oxygen and specific conductivity were measured *in situ* with portable instruments calibrated in the field and Secchi depth (m) was used as an estimate of water transparency. Other parameters like alkalinity (mg HCO_3^- L^{-1}), total hardness (mg $CaCO_3$ L^{-1}), total suspended solids (mg L^{-1}), biological oxygen demand after 5 days (BOD_5, mg O_2 L^{-1}), chemical oxygen demand (COD, mg O_2 L^{-1}), nitrates (µg NO_3^--N L^{-1}), nitrites (µg NO_2^--N L^{-1}), ammonia (µg NH_4^+-N L^{-1}), total phosphorus (µg P L^{-1}) and soluble reactive phosphorus (µg PO_4^{3-}-P L^{-1}) were determined in laboratory, following standard methods for water chemical analyses according to APHA (1995).

Samples for chlorophyll a analysis were filtered using Whatman GF:C glass fiber filters and chlorophyll a was extracted for 24 h in 8 mL acetone (90%) at 4ºC in the dark. After extraction, Chl a was measured spectrophotometrically and corrected for degradation products using the equations given by LORENZEN (1967).

Epilithic diatom samples were treated using hot hydrogen peroxide (120 vols.) and HCl (37%) in order to obtain suspensions of clean frustules. Permanent slides were mounted with Naphrax®. Diatoms were identified to specific or subspecific level using light microscopy (LM) (Leica DMRX with 100x oil immersion objective). At least 400 valves were identified and counted from each slide to estimate the relative abundance of each taxon (INAG 2008). The identification was based on reference floras (e.g. KRAMMER & LANGE-BERTALOT, 1986, 1988, 1991a, b) as well as on recent bibliography. Furthermore, the samples were identified and counted by a small team, in order to decrease the identification effects, which can be the main source of variability according to PRYGIEL et al. (2002) and KAHLERT et al. (2009).

5.2.3 Determination of diatom metric (SPI)

Diatom abundances were used to calculate the Specific Pollution sensitivity Index (SPI) (COSTE in CEMAGREF 1982). Although the SPI has been originally developed for assessing the quality of running waters, it was selected because it is the only diatom index based on the autecological parameters of virtually all known taxa at species or subspecific levels. It has been recommended as

reference index for several Iberian basins (GOMÀ et al. 2004, 2005; BLANCO et al. 2007, 2008) and has already been successfully used for water quality assessment in lentic facies (BLANCO et al. 2004). The Specific Pollution sensitivity Index (SPI) is based on the ZELINKA & MARVAN (1961) formula, i.e., assigning a pair of individual values (pollution tolerance – S and stenoecy degree - V) to the taxa present in the diatom assemblages and was determined using the OMNIDIA v. 5.3 software (LECOINTE et al. 1993).

5.2.4 Statistical analysis

The species (log (x+1) transformed) and environmental data (square root-transformed) were analyzed by means of multivariate analyses. The environmental data were analysed by a Principal Component Analysis (PCA), based on a matrix of 72 sampling sites x 16 environmental parameters. A Detrended Correspondence Analysis (DCA) was applied to the species dataset to verify the type of response of the data (unimodal or linear), according to the length of the gradient. The species data showed an unimodal response, with a maximum gradient length above 4 SD (4.135), therefore the results of the DCA analysis were taken into account, with a matrix of 72 sampling sites x 145 diatom taxa (only diatom taxa with abundance above 2% were considered and downweighting of rare taxa was performed). These multivariate analyses were performed using CANOCO v. 4.5 software (TER BRAAK & ŠMILAUER 2002).

Statistical differences between the groups i.e. hydromorphological types, reference/non-reference conditions (INAG pre-established classification), reference/non-reference conditions (SPI based) and seasons, were assessed by means of the non-parametric Analysis of Similarity (ANOSIM) (CLARKE 1993) based on species abundances. This methodology employs R statistics to examine the differences between groups of community samples (defined a priori) using permutation/randomisation methods on the similarity matrix. For each group a Similarity Percentage – species contributions (SIMPER) was used to determine which species contributed most to the differences between groups and to the similarity within each group, using the Bray-Curtis dissimilarity index (CLARKE & GORLEY 2001). Both the ANOSIM and SIMPER analyses were performed using PRIMER® Version 5.2.0 (CLARKE & GORLEY 2001).

5.3 Results

A total of 322 diatom taxa belonging to 70 genera were identified in the 72 analysed samples. 186 diatom taxa were identified with abundances above 1% in at least one sample. The most represented genera were *Nitzschia* (43 taxa), *Gomphonema* (28), *Navicula* (27), *Eunotia* (18), *Fragilaria* (14) and *Cymbella* (12).

The data set had wide ranges for Chl a (1.0-39.7 µg L^{-1}), TP (17-895 µg P L^{-1}), nitrates (68-1292 µg NO_3^--N L^{-1}), pH (6.9-8.4) and Secchi depth (1.4-6.3 m). These variations in the environmental characteristics of the reservoirs mainly reflected differences in terms of land use and anthropogenic disturbance. Additionally, total hardness (1.8-196.8 mg $CaCO_3$ L^{-1}) and conductivity (14-545 µS cm^{-1})

had also a broad range of values (Table 5.2), which represented the natural geological variability within the study area.

The PCA ordination (Figure 5.2) showed graphically the distribution of the sampling sites according to the environmental parameters. The eigenvalues of the first two axes were 0.731 and 0.154, explaining 71.3% and 17.2%, respectively of the cumulative variance of the environmental dataset.

The PCA plot showed that the first two axes allowed a separation of the reservoirs based on the hydromorphological types and on organic contamination. Along the first axis the parameter Secchi depth, located on the negative part of the axis was clearly influencing the reservoirs Vilarinho das Furnas and Santa Luzia, Marateca, Varosa and Torrão and was opposed to all the other variables located in the positive part of the axis, together with all the other reservoirs. There was therefore an opposition between the Secchi depth versus all the other pressure variables, reflecting a degradation gradient. Along the second axis there was a clear separation between the reservoirs belonging to the type Main Courses, located in the negative part of the axis (mainly influenced by the variables total hardness, nitrates, soluble reactive phosphorus and total phosphorus) and the reservoirs belonging to the types South (mainly influenced by the variables BOD_5, temperature, ammonia, TSS, Chl *a*, COD and pH) and North (influenced by the sechi depth variable). Within the group Main Courses the reservoirs of the Douro and Tejo rivers were separated: the group of Crestuma, Valeira, Pocinho and Régua reservoirs mainly influenced by nitrates, while Belver and Fratel reservoirs were mainly influenced by soluble reactive phosphorus and total phosphorus.

This distribution of the reservoirs according to the hydromorphological types and the environmental parameters that contributed to this distribution was also put into evidence by the environmental characterization of the reservoirs (Table 5.2). For instance, the values of total hardness, which presented different ranges according to the hydromorphological types previously defined, showed the lowest values in the type North (absolute values: 0.1-67.1 mg $CaCO_3$ L^{-1}; mean values: 1.8-29.6 mg $CaCO_3$ L^{-1}), intermediate values in the South (absolute values: 0.1-128.0 mg $CaCO_3$ L^{-1}; mean values: 24.8-63.5 mg $CaCO_3$ L^{-1}) and highest values in the Main Courses (absolute values: 6.7-228.0 mg $CaCO_3$ L^{-1}; mean values: 106.0-196.8 mg $CaCO_3$ L^{-1}). Also the conductivity values reflected the differences between the hydromorphological types, presenting generally the lowest values in the type North (absolute values: 1-280 µS cm^{-1}; mean values: 14-200 µS cm^{-1}, except for the winter campaign in Marateca Reservoir (620 µS cm^{-1}), intermediate values in the South (absolute values: 5-420 µS cm^{-1}; mean values: 150-394 µS cm^{-1}) and highest values in the Main Courses (absolute values: 5-745 µS cm^{-1}; mean values: 243-545 µS cm^{-1}). The Secchi depth, on the other hand, had the lowest absolute values in the Main Courses (absolute values: 0.1-3.5 m; mean values: 2.1-2.6 m), the intermediate values in the South (absolute values: 0.3-4.8 m; mean values: 1.7-3.7 m) and the highest values in the North (absolute values: 0.5-7.4 m; mean values: 1.4-6.3 m), which is clearly presented in the PCA analysis, where it is shown that this is the parameter that contributes most to the identification of the type North (Santa Luzia, Vilarinho das Furnas, Marateca, Varosa and Torrão) (Figure 5.2).

The DCA plot (Figure 5.3) graphically shows the distribution of the sampling sites according to diatom assemblages. The eigenvalues of the first two axes were 0.472 and 0.254, explaining 11.4% and

6.2%, respectively of the cumulative variance of the species dataset. The analysis of the DCA results revealed a tendency of the grouping of reservoirs according to the established hydromorphological types and revealed a separation of the reference and non-reference ecological conditions of the reservoirs in the types North and South. Nevertheless, due to the low values of explanation of each axis, this tendency has to be confirmed by further analyses.

Taking into account the results of the PCA and DCA analysis as well as the interpretation of the environmental characterization of the reservoirs, previously presented, we performed an ANOSIM analysis to validate the three hydromorphological types. Nevertheless, since the validation of the hydromorphological types should be based on reservoirs with Good or High ecological potential, we only considered the reservoirs with SPI $\geq$ 13 (following the original boundaries between the quality classes) to perform the validation of the typology. The ANOSIM analysis showed that the diatom communities allowed the separation of all the a priori defined hydromorphological types (North, Main Courses, South) (n=52) (Global R=0.412, $p<0.001$), the type Main Courses being more distinct from the types South (R=0.568) and North (R=0.407) than the types North and South (R=0.341) (Table 3), which is in accordance with the PCA ordination, since the group formed by the types North and South was separated from the Main Courses along the second axis (17.2%), while the types North and South were somehow separated along the first axis (71.3%). The SIMPER results partly confirmed this pattern, with an average dissimilarity of 82.46% between the types North and Main Courses, of 83.51% between the Main Courses and South and of 82.89% between the North and South types.

Table 5.2 Environmental characterization of the studied reservoirs (mean values of four seasons ± standard deviation).

Reservoir name	Alkalinity	Secchi depth	Total hardness	Total suspended solids	BOD_5	COD	Nitrates	Nitrites	Ammonia	Total phosphorus	Phosphates	Chlorophyll *a*	Oxygen	Conductivity	Temperature	pH
	mg HCO_3 L^{-1}	m	mg $CaCO_3$ L^{-1}	mg L^{-1}	mg O_2 L^{-1}	mg O_2 L^{-1}	µg N L^{-1}	µg N L^{-1}	µg N L^{-1}	µg P L^{-1}	mg P L^{-1}	µg L^{-1}	mg L^{-1}	µS cm^{-1}	℃	
V. Furnas	4.0±1.5	6.3±0.9	1.8±0.1	1.0±0.3	0.9±0.3	3.3±0.8	68±37	3±1	39±0	17±7	2±0	1.1±0.5	8.4±1.1	14± 1	15.7±6.5	6.9±0.4
Meimoa	25.0±0.0	2.5±0.5	9.9±0.8	6.0±1.4	3.0±0.0	11 .5±3.0	305±75	15±0	62±0	63±5	22±0	12.6±13.0	9.4±1.4	38±3	16.1±7.3	7.8±0.3
Santa Luzia	25.5±1.0	3.0±1.7	7.5±0.5	5.0±0.0	3.0±0.0	10.0±0.0	3 95±159	15±0	81±39	65±10	22±0	2.7±1.5	8.8±0.6	31±3	1 6.5±7.0	7.5±0.2
Marateca	25.0±0.0	1.4±0.8	9.7±0.3	9.3±3.4	3.0±0.0	23.5±13.7	356±157	15±0	109±133	60±0	20±4	13.7±11.3	9.9±0.9	200±280	17.7±7.9	8.0±0.8
Torrão	22.1±23.2	3.1±1.0	29.6±25.7	2.5±1.5	1.1±0.6	5.3±1.7	903±157	12±3	110±85	103±36	6±5	2.7±1.5	8.5 ±1.7	90±64	17.6±7.1	7.6±0.6
Varosa	14.4±8.7	2.4±1.1	15.2±7.9	3.9±4.5	2.7±1.2	1 5.7±16.4	514±418	12±5	107±79	232±300	10±8	39.7±55.6	9.7±2.0	74±28	18.1±8.0	8.1±1.2
Belver	76.8±10.3	2.4±0.1	188.5±48.3	2.9±0.8	1.8± 0 .3	13.5±3.6	68±37	3±1	39±0	17±7	2±0	13.7±12.6	10.5±1.1	545±332	17.4±5.8	8.2±0.5
Valeira	70.9±41.4	2.6±0.4	125.8±6.7	2.9±0.8	1.4±0. 5	7.7±2.0	1174±757	27±16	60±43	193±48	17±12	5.4±4.8	9.7±1.8	280±62	16.5±7.3	8.3±0.3
Pocinho	88.5±14.2	2.2±0.9	128.5±25.4	3.9±3.2	1.6±1 .2	8.0±1.0	1292±700	19±7	39±0	243±88	21±10	5.2±2.9	10.3±2.3	286±42	17.7±7.2	8.3±0.6
Fratel	85.5±27.0	2.6±0.8	196.8±34.4	2.4±1.2	1.3±0. 5	12.8±2.7	982±285	19±24	41±4	895±261	153±58	4.2±2. 0	11.1±4.5	529±352	17.3±5.3	8.1±0.9
Régua	84.3±20.9	2.2±0.9	113.6±33.0	4.0±2.3	1.7±0.4	8.4±1.3	976±461	11±10	39±0	211±49	14±3	6.6±4.8	9.8 ±1.5	254±57	16.7±7.2	8.3±0.5
Crestuma	75.3±7.0	2.1±0.3	106.0±8.1	3.2±1.7	1.2±0. 3	8.0±3.7	1213±470	14±9	48±15	184±48	16±11	3.3±2.4	9.0±1.5	243±38	16.9±7.0	8.0±0.4
Odeleite	40.5±0.7	2.7±1.4	42.8±1.0	5.8±1.5	3.0±0.0	10.3±0.5	339±171	15±0	74±23	65±10	22±0	4.2±3.5	8.5 ±1.0	150±6	20.3±5.7	8.1±0.5
Santa Clara	44.5±2.5	3.7±1.3	63.5±2.1	5.0±0.0	3.0±0.0	10.5±0.6	243±22	15±0	62±0	63±5	22±0	1.0±0.6	8.4±1.0	250±5	15 .8±10.8	8.0±0.2
T. Grande	45.5±5.6	1.8±0.9	52.5±2.9	19.3±21.1	3.0±0.0	18.5±1.3	468±400	16±2	143±73	110±87	22±0	15 .3±18.2	8.9±3.4	275±18	20.7±5.4	7.6±0.3
Monte Novo	144.0±9.4	1.7±1.0	32.1±63.9	9.0±5.2	6.0±3.5	21.5±1. 9	327±129	20±6	277±180	60±0	22±0	7.8±4.3	7.9±2.7	39 4±22	19.4±7.9	8.2±0.5
Montargil	46.8±5.2	1.7±0.3	42.0±2.3	6.5±1.7	3.0±0. 0	19.0±4.1	429±167	19±5	153±82	70±20	22±0	16.8±9.4	9.4±2.3	175±11	19.5±6.9	8.4±1.0
Maranhão	138±15.3	1.8±0.4	24.8±49.4	6.8±2.4	3.0±0. 0	22.8±5.0	767±603	24±17	95±41	70±12	25±7	9.4±11.7	9.0±6.7	342±46	19.7±7.3	7.3±2.5

Table 5.3 The hydromorphological types of reservoirs and the sampling seasons, using SIMPER analysis, percentage breakdown of average dissimilarity between the reservoirs pre-classified as reference/non-reference, the reservoirs classified as reference/non-reference according to SPI values. For the presentation of the Average dissimilarity (%) the following abbreviations have been used: N=North, MC= Main Courses, S=South, W=Winter, S=Spring, Su=Summer and A=Autumn. Statistical and global R values for the pairwise analysis of similarity (ANOSIM) tests are presented. Only $p<0.001$ was regarded as significant.

Factors	Groups	Average similarity (%)	Average dissimilarity (%)	Anosim (statistical R)	Anosim (Global R)
Hydromorphological types (n=52)	North Main Courses South	25.17 34.50 25.09	N/MC=82.46 MC/S=83.51 N/S=82.89	R = 0.407*** R = 0.568*** R = 0.341***	Global R = 0.412***
Ref/Non-reference (pre-established) (n=72)	Reference Non-reference	18.94 24.17	81.15		Global R = 0.123***
Ref/Non-reference (SPI based) (n=72)	Reference Non-reference	27.65 23.16	85.94		Global R = 0.518***
Seasons (n=72)	Winter Spring Summer Autumn	19.84 20.13 18.89 21.58	W/S=79.49 W/Su=82.10 S/Su=80.42 W/A=79.35 S/A=78.37 Su/A=79.05	R = -0.025 R = 0.078 R = 0.009 R = 0.006 R = -0.019 R = -0.007	Global R = 0.008 (n.s)

The most characteristic diatom taxa of each type (Average contribution > 2% for intra-type similarities) are presented in the Table 5.4 and allow us to see that Achnanthidium minutissimum (ADMI) was the species that mostly contributed to all the intra-type similarities. Since this species was common to all the types, we considered as main indicator species of the hydromorphological types the species that followed in terms of % contribution, until a contribution of 5%, since the other accompanying species have lower sensibility. Thus, the main indicator taxa of the hydromorphological type North are: *Fragilaria vaucheriae* (FVAU) (S=3.4, V=1.0), *Discostella stelligera* (DSTE) (S=4.2, V=1.0) and *Aulacoseira tenella* (AUTL) (S=4.8, V=1.0); of the type Main Courses: *Nitzschia fonticola* (NFON) (S=3.5, V=1.0) and *Staurosira binodis* (S=4.0, V=1.0) and of the type South *Cyclotella ocellata* (COCE) (S=3.0, V=1.0). The majority of these main indicator taxa is also visible in the DCA plot with the species and reservoirs (Figure 5.23). According to VAN DAM et al. (1994) classification, *Fragilaria vaucheriae* is an α-mesosaprobous and eutraphentic species, *Nitzschia fonticola* is β-mesosaprobous and meso-eutraphentic, *Staurosira binodis* is oligosaprobous and meso-eutraphentic and *Cyclotella ocellata* is oligosaprobous and meso-eutraphentic. The occurrence of several centric diatoms among the indicator species of the hydromorphological types lead us to check the information available about their life forms. Thus, according to DENYS (1991), only *Aulacoseira ambigua*, *Stephanodiscus hantzschii* and *Cyclostephanos dubius* are euplanktonic taxa, probably present due to deposition on stones, while *Discostella stelligera*, *Cyclotella ocellata* and *Melosira varians* are tychoplanktonic. There is no information available about *Aulacoseira tenella*.

Due to the absence of a clear discrimination by PCA and DCA ordinations of the reservoirs previously considered as presenting reference and non-reference ecological conditions (Figure 5.2 and 5.3), we attempted to use the SPI values to characterize the ecological potential of the reservoirs. The SPI determined for each reservoir, based on the average of the four seasonal values, varied from 9.6 to 19.7, reflecting an ecological potential ranging from moderate to high (Table 5.1). Since reference condition reservoirs should present a high ecological potential (SPI $\geq$ 17, according to the original boundary between the quality classes), the pre-classification of reservoirs as reference or non-reference ecological conditions is not clearly in accordance with the SPI results, as can be seen in Table 5.1. Therefore, an ANOSIM analysis was performed to check if there were differences between the reservoirs previously classified as reference or non-reference ecological conditions. This analysis proved that there were no differences between the diatom communities of the reservoirs previously classified as reference and non-reference ecological conditions, because low values of R (below 0.25) occur if the groups bear no relationship, despite the fact of being significant (n=72) (Global R=0.123). Afterwards, we performed another ANOSIM analysis to test if the arrangement of the reservoirs with reference ecological condition based on the SPI values was valid. The result showed that there were statistically significant differences between the groups (n=72) (Global R=0.518, $p<0.001$) (Table 5.3). The SIMPER analyses are in accordance with this result, because the average dissimilarity between the reservoirs with reference and non-reference ecological conditions increased when we considered as presenting reference conditions the reservoirs with SPI $\geq$ 17 (from 81.15% to 85.94%) (Table 5.3). On the basis of these results, we took into account the SPI results and therefore considered only Vilarinho das Furnas, Meimoa, Santa Luzia and Odeleite as reference reservoirs, being Vilarinho das

Furnas, Meimoa and Santa Luzia reference reservoirs for the hydromorphological type North, Odeleite the only reference for the type South and the lack of reference reservoirs for the type Main Courses was proved. This is into accordance with the low values of the contamination variables (average values of the four seasons), such as nitrates: Vilarinho das Furnas (68 NO_3^--N L^{-1}), Meimoa (305 NO_3^--N L^{-1}), Santa Luzia (395 NO_3^--N L^{-1}) and Odeleite (339 NO_3^--N L^{-1}); nitrites: Vilarinho das Furnas (3 µg NO_2^--N L^{-1}), Meimoa (15 µg NO_2^--N L^{-1}), Santa Luzia (15 µg NO_2^--N L^{-1}) and Odeleite (15 µg NO_2^--N L^{-1}); chemical oxygen demand: Vilarinho das Furnas (3.3 mg O_2 L^{-1}), Meimoa (11.5 mg O_2 L^{-1}), Santa Luzia (10.0 mg O_2 L^{-1}) and Odeleite (10.3 mg O_2 L^{-1}); ammonia: Vilarinho das Furnas (39 µg NH_4^+-N L^{-1}), Meimoa (62 µg NH_4^+-N L^{-1}), Santa Luzia (81 µg NH_4^+-N L^{-1}) and Odeleite (74 µg NH_4^+-N L^{-1}); total phosphorus: Vilarinho das Furnas (17 µg P L^{-1}), Meimoa (63 µg P L^{-1}), Santa Luzia (65 µg P L^{-1}) and Odeleite (65 µg P L^{-1}) and soluble reactive phosphorus: Vilarinho das Furnas (2 µg PO_4^{3-}-P L^{-1}), Meimoa (22 µg PO_4^{3-}-P L^{-1}), Santa Luzia (22 µg PO_4^{3-}-P L^{-1}) and Odeleite (22 µg PO_4^{3-}-P L^{-1}).

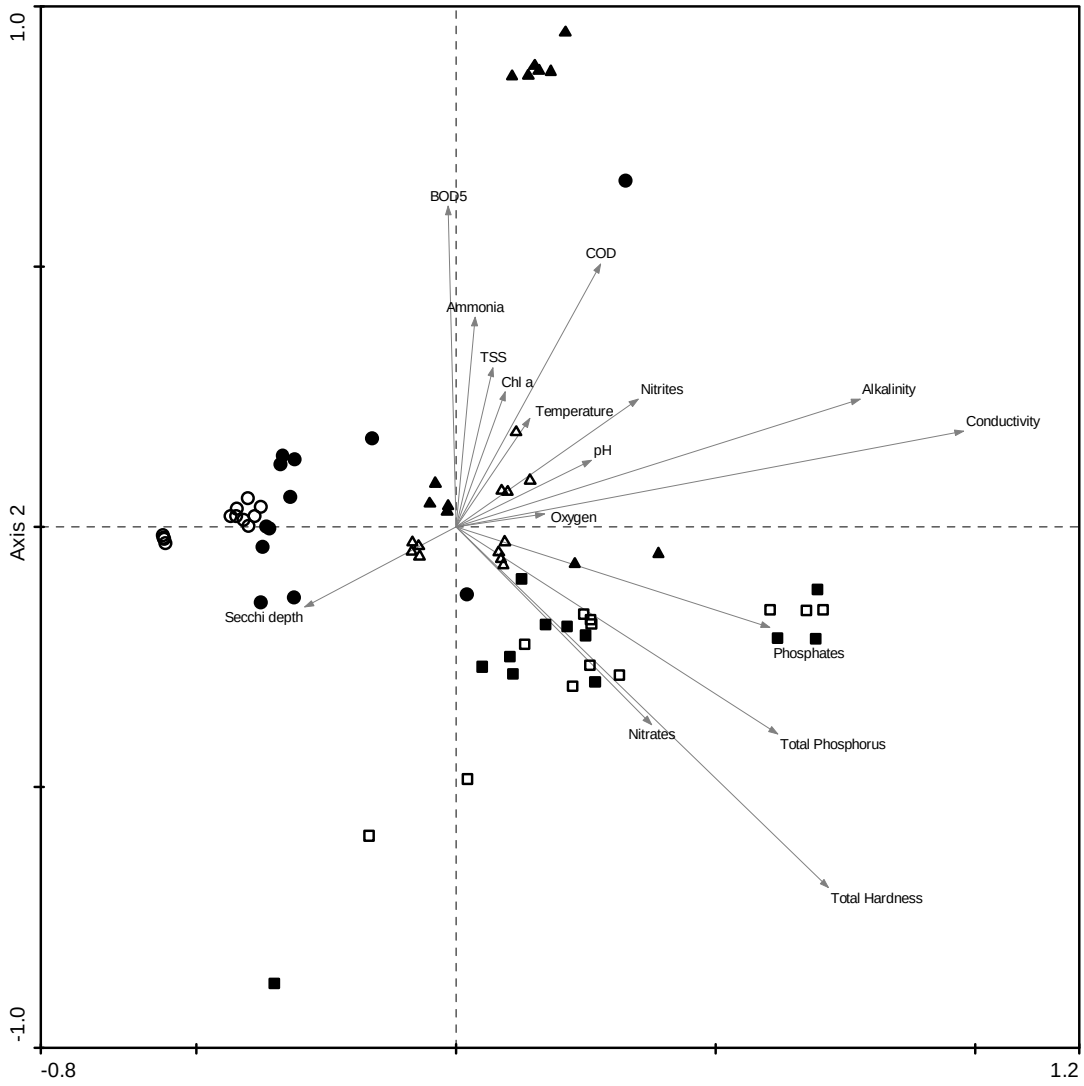

Figure 5.2 Principal Component Analysis (PCA) plot for the first two axes with the reservoirs sampled and environmental parameters. Sampling sites are classified according to their hydromorphological

type and as reference and non-reference. White circle: North reference. Black circle: North non-reference. White square: Main Courses reference. Black square: Main Courses non-reference. White triangle: South reference. Black triangle: South non-reference.

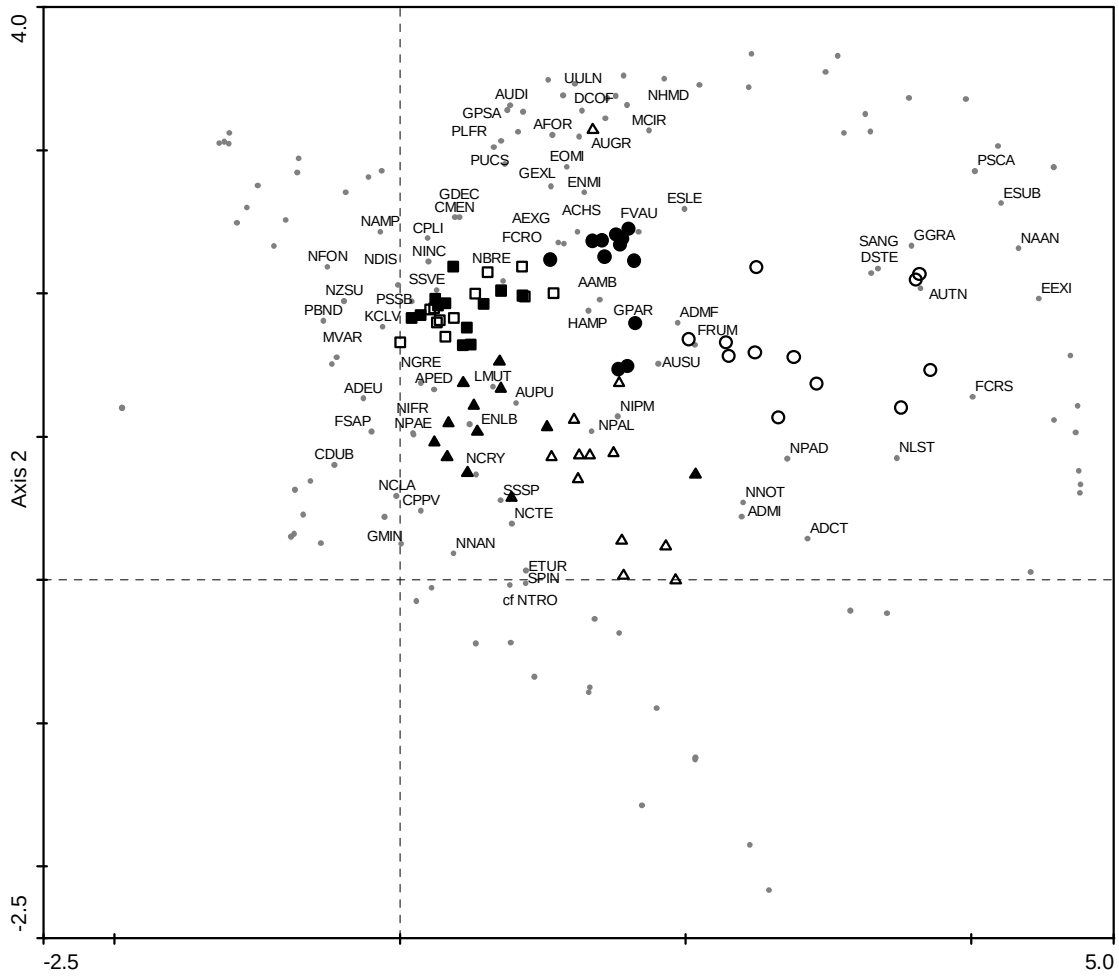

Figure 5.3 Detrended Correspondence Analysis (DCA) plot for the first two axes with the sampling sites and the diatom taxa. Sampling sites are classified according to their hydromorphological type and as reference and non-reference. White circle: North reference. Black circle: North non-reference. White square: Main Courses reference. Black square: Main Courses non-reference. White triangle: South reference. Black triangle: South non-reference.

Table 5.4 Average contribution (%) of the taxa mainly responsible for intra-type similarities.

North		Main Courses		South	
Taxon	**%**	**Taxon**	**%**	**Taxon**	**%**
Achnanthidium minutissimum (KÜTZING) CZARNECKI	28.20	*Achnanthidium minutissimum* (KÜTZING) CZARNECKI	8.33	*Achnanthidium minutissimum* (KÜTZING) CZARNECKI	50.23
Fragilaria vaucheriae (KÜTZING) J.B. PETERSEN	9.20	*Nitzschia fonticola* GRUNOW	7.42	*Cyclotella ocellata* PANTOCSEK	14.21
Discostella stelligera (CLEVE & GRUNOW) HOUK & KLEE	8.70	*Staurosira binodis* (EHRENBERG) LANGE-BERTALOT	7.15	*Navicula veneta* KÜTZING	3.48
Aulacoseira tenella (NYGAARD) SIMONSEN	5.47	*Planothidium frequentissimum* (LANGE-BERTALOT) LANGE-BERTALOT	4.41	*Navicula gregaria* DONKIN	2.63
Gomphonema parvulum (KÜTZING) KÜTZING	4.52	*Staurosira venter* (EHRENBERG) CLEVE & MÖLLER	3.75	*Encyonopsis subminuta* KRAMMER & E. REICHARDT	2.47
Fragilaria rumpens (KÜTZING) G.W.F. CARLSON	4.22	*Melosira varians* C. AGARDH	3.50	*Nitzschia palea* (KÜTZING) W. SMITH	2.24
Achnanthidium catenatum (BÍLÝ & MARVAN) LANGE-BERTALOT	3.47	*Stephanodiscus hantzschii* GRUNOW	3.46	*Achnanthidium catenatum* (BÍLÝ & MARVAN) LANGE-BERTALOT	2.12
Eolimna minima (GRUNOW) LANGE-BERTALOT	2.61	*Amphora pediculus* (KÜTZING) GRUNOW	3.36	*Gomphonema pumilum* (GRUNOW) E. REICHARDT & LANGE-BERTALOT	2.05
Aulacoseira ambigua (GRUNOW) SIMONSEN	2.09	*Navicula cryptotenella* LANGE-BERTALOT	3.31		
		Fragilaria vaucheriae (KÜTZING) J.B. PETERSEN	3.10		
		Cocconeis lineata EHRENBERG	2.82		
		Nitzschia amphibia GRUNOW	2.78		
		Navicula gregaria DONKIN	2.74		
		Eolimna minima (GRUNOW) LANGE-BERTALOT	2.59		
		Achnanthidium subhudsonis (HUSTEDT) H. KOBAYASI	2.58		
		Fragilaria crotonensis KITTON	2.37		
		Nitzschia frustulum (KÜTZING) GRUNOW	2.35		
		Rhoicosphenia abbreviata (C. AGARDH) LANGE-BERTALOT	2.34		
		Cyclostephanos dubius (FRICKE) ROUND	2.10		

Finally, to verify if there are significant differences between the sampling seasons, an ANOSIM analysis has been performed. The results obtained showed that the diatom communities did not allow the discrimination between the sampling seasons (Global R=0.008, *p*=0.321) (Table 5.3). In fact, the R values for inter-groups comparisons were all very low, negative R values being obtained for some of the analyses (Winter/Spring R=-0.025; Spring/Autumn R=-0.019; Summer/Autumn R=-0.007), which means that the most similar samples are outside of the considered groups, since a R value of -1 indicates that the most similar samples are all outside of the groups (SEABY & HENDERSON 2007).

5.4 Discussion and conclusion

In general, the values of total phosphorus and Secchi depth are similar to those presented by CABECINHA et al. (2009a), based on data measured from 1996 to 2004. However, for several reservoirs (i.e. Belver, Valeira, Pocinho, Régua, Crestuma, Torrão and Varosa), the values of chlorophyll *a* were higher in the present study based on data obtained in 2006, which can indicate a probable impairment of the studied reservoirs.

The analysis of diatom communities allowed a clear separation between the three pre-established hydromorphological types (North, Main Courses, South), characterized by different hydromorphological features and water chemical characteristics, as seen in Table 5.1, Table 5.2 and Figures 5.2 and 5.4. The reservoirs located in the Main Courses (Tejo and Douro) can be separated from the other two groups because they are considered “run-of-river” reservoirs, with very short residence times, as can be seen by the presence of perceptible flow (Table 5.1). CABECINHA et al. (2009a) already discussed this pattern in their study on Portuguese reservoirs based on environmental variables and phytoplankton assemblages. In the latter study, a separation is proved between reservoirs located in the main rivers and those located in the tributaries with higher residence time. The reservoirs in the Main Courses are influenced by contamination parameters, such as nitrates and soluble reactive phosphorus, which is in accordance with the fact that these are densely populated basins.

Indices based on littoral diatoms have therefore the potential to be used as ecological indicators for reservoirs, as is the case for other lentic systems such as shallow ponds (KITNER & POULÍČKOVÁ 2003; BLANCO et al. 2004), coastal wetlands (DELLA BELLA et al. 2007; TROBAJO 2007) and mountain lakes (POULÍČKOVÁ et al. 2004). However, the need for further studies to compare the performance of the different sampled substrates must be stressed, due to the fact that water quality diagnosis may change in accordance with the diatom substrate investigated (POULÍČKOVÁ et al. 2004). Stone and artificially placed old reed substrata may be appropriate for biomonitoring of shallow soda lakes in both spring and autumn periods because they showed highly similar results regarding all measured features (ÁCS et al. 2008).

There were no significant differences between the diatom communities of the reservoirs previously classified as presenting reference and non-reference ecological conditions, as could be seen in the DCA plot with diatom taxa and reservoirs sampled and in the ANOSIM analysis. These results show

that there is a need for a better characterization of the ecological potential of the Portuguese reservoirs, since there was a clear separation when SPI values were considered as a complementary variable to classify the ecological condition of the reservoirs as reference and non-reference. Our results show that Vilarinho das Furnas, Meimoa, Santa Luzia and Odeleite were the only reservoirs which presented a high ecological potential and that can truly be considered as Maximum Ecological Potential reservoirs for the biological element diatoms. This is related to the fact that Vilarinho das Furnas and Meimoa reservoirs are located in the protected areas of Peneda-Gerês National Park and Malcata Natural Reserve, respectively. The reservoirs Vilarinho das Furnas, Meimoa, Santa Luzia belong to the hydromorphological type North and Odeleite reservoir belongs to the type South. Thus, Maximum Ecological Potential reservoirs for the type Main Courses are still missing. In the eventual impossibility to find Maximum Ecological Potential reservoirs for this type in Portugal, a search could be made in Spain, as these are located in international river basins. Since reservoirs are water bodies identified as Heavily Modified Water Bodies (HMWB), the reference conditions on which classification is based are within the range of Maximum Ecological Potential (MEP). The MEP represents the maximum ecological quality that could be achieved for these systems, once all mitigation measures that do not have significant adverse effects on its specified use or on the wider environment have been applied (GIG 2007). Following the recommendations of the GIG (2007), although the MEP biological conditions shall reflect those associated with the closest comparable water body type when it is not possible to identify a comparable natural lake, it will be necessary to identify a HMWB (reservoir) of the same type, being subject only to the impacts coming from the hydromorphological alterations resulting in their classification as heavily modified water body.

Selection of Maximum Ecological Potential reservoirs in Portugal was mainly based on general parameters of the whole watershed such as the urban area and the type and extension of agricultural activities, while criteria more directly related to the chemical characteristics of the water have not been considered at this stage. Therefore, all of the studied reservoirs in the Main Courses can not be considered as Maximum Ecological Potential reservoirs for this type, because these water courses (Tejo and Douro) belong to international river basins and their trophic status is a consequence of the important anthropogenic pressures that characterize both basins, mainly due to intensive agriculture practiced upstream in Spain (BLANCO et al. 2008; CABECINHA et al. 2009a) which contributes to the poor quality of waters when reaching Portugal (BORDALO et al. 2006).

Contrastingly, diatom communities did not discriminate between the seasons of the year, which is consistent with the lack of noticeable differences in the chemical characteristics of the water throughout the duration of this study. TOLOTTI (2001) presented similar results for two high mountain lakes of the Adamello-Brenta Regional Park (Trentino, Italy) which were monthly sampled during the ice-free period, without a significant improvement of the diatom-based trophic classification, probably as a result of the more pronounced temporal stability and slow growth of the benthic algae compared to phytoplankton. Nevertheless, KING et al. (2006) stated that pronounced seasonal and successional changes have been recorded in littoral diatom assemblages in lakes, whereas KELLY et al. (2009) affirmed that assemblages in littoral regions of lakes are highly dynamic and samples taken in one occasion provide a short “environmental history”. Therefore, further studies of Portuguese and

Spanish reservoirs should be performed in order to validate the preliminary results obtained in this study, since for monitoring purposes a balance should be found between the sampling intensity that gives a robust classification in a practical time period and the need to avoid possible misinterpretations due to pseudo-replication or the influence of seasonality (KELLY et al. 2009). Furthermore, since the ultimate objective of the WFD is to restore the impacted water bodies to "Good Ecological Potential", it is vital to provide a better understanding of the performance of diatom metrics over time.

Although our results demonstrate the value of littoral epilithic diatoms in the assessment of the ecological potential of reservoirs, it must still be stated that the knowledge about the species autoecology must be improved, since there is a lack of ecological information about several species characteristic of the hydromorphological types, such as *Achnanthidium catenatum*, *A. subhudsonis*, *Aulacoseira tenella*, *Discostella stelligera*, *Gomphonema pumilum* complex and *Tabellaria pseudoflocculosa*. Among the most important species for the definition of the types was *Fragilaria vaucheriae*, which is an α-mesosaprobous and eutraphentic species complex. Other taxa such as *Eolimna minima*, *Gomphonema parvulum*, *Navicula veneta*, *Nitzschia frustulum* and *Stephanodiscus hantzschii* were also present and classified as β-mesosaprobous to α-meso-polysaprobous and eutraphentic to hypereutraphentic, according to VAN DAM et al. (1994). The presence of these species is most likely related to the difficulties to select unimpacted reservoirs in the country, even if to validate the abiotic typology only the reservoirs that presented good or high ecological potential were considered.

Littoral epilithic diatoms proved to be a valuable element to validate the three hydromorphological types previously defined by the INAG and to identify the possible Maximum Ecological Potential reservoirs within each hydromorphological type. This constitutes a first step for the further indices selection and classification system (with the borders between the different quality classes).

As a concluding remark, this study confirms that biological methods based on epilithic littoral diatoms are a valuable complement to the other biological elements for the assessment of the ecological potential of reservoirs in Portugal in accordance with the requirements of the Water Framework Directive.

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Chapter 6

GENERAL CONCLUSIONS AND PERSPECTIVES OF FUTURE RESEARCH

6 General conclusions and perspectives of future research

All the objectives proposed for this PhD study have been achieved. This research helped to put into evidence the high freshwater diatom diversity of Portugal, revealed by the revision of the diatom taxa already cited in the entire bibliography and examined in the course of the survey of watercourses and reservoirs from the whole country.

In total, 1381 diatom taxa were cited for the whole country (Archipelagos of Azores and Madeira included), based on the analysis of 173 publications. These publications include all kinds of works where continental diatoms can be mentioned, such as phytoplankton surveys, paleolimnological investigations and studies on the use of diatoms for the monitoring of water quality. Nevertheless only PhD thesis or published studies were considered, in order to decrease the risk of the inclusion of works with less reliable identifications.

During the present survey, based on the analysis of 363 sampling sites in watercourses throughout the country and in 18 reservoirs seasonally sampled, a total of 570 diatom taxa were inventoried. From which 170 were presented with abundance above 5% in at least one sampling site and are almost all represented in the iconographic atlas. There were several taxa which posed identification difficulties and are represented by cf. and aff. notations.

Some taxa could not be identified to species level, and therefore a detailed study was made. The majority of these taxa were illustrated in detail under light and scanning electron microscopy. Some of them were already validly submitted as new species, e.g. two *Eunotia* species to be published in the beginning of 2011 in the volume of Diatoms of Europe about *Eunotia* species), *Achnanthidium pseudolineare* Van de Vijver, Novais & Ector (in VAN DE VIJVER et al. 2010, a paper accepted to be published in the journal *Algological Studies*) and *Achnanthidium caravelense* NOVAIS & ECTOR (NOVAIS et al. 2010, presented in this thesis). Nevertheless there are still several taxa that have a high probability of being new but that need further studies, e.g. *Geissleria* sp., *Nupela* sp., 7 different *Achnanthidium* taxa, *Pinnularia* sp., *Eolimna* spp. and *Eunotia* aff. *soleirolii,* among others. To decide if these taxa are new there is still needed a thourough study of each group with a comparison with morphologically similar species (including the investigation of the type material), detailed morphometric analysis (a geometric morphometric analysis may be useful in cases to detect subtle differences) and a detailed study of their ecological preferences. Furthermore, a total of 13 taxa are new citations for the Iberian Peninsula and 49 are new citations for Portugal. Such a high number of new records is probably due to the use of more recent bibliography, where species complexes that were previously considered together have been recently splitted. Furthermore, the survey of regions of the country that have never been deeply studied before has also greatly contributed to the high diversity encountered. Nevertheless, the high number of first records and new taxa prove that the Portuguese freshwater diatom flora was indeed quite unexplored and there is still a need for further studies to complement the present floristic study of the country. Especially since there is a lack of

studies in a great part of the territory, that were sampled only for the implementation of the Water Framework Directive in the country and which floristic results were never published.

From this work it becomes clear that a deep study of diatom species complexes should be based not only in morphological and ultrastructural features, but also in terms of ecological preferences, which is the case of both groups presented in the papers constituting the chapter 4. It was proved that there are recognizable differences in the ecological preferences of the taxa within the *Gomphonema rosenstockianum* and *G. tergestinum* group, which can also serve as a helpful tool for the identification. It would thus be interesting to perform a similar study at a wider geographical scale, in order to increase and to support the current knowledge about the taxonomy, autoecology and biogeography of this species complex. Furthermore, as future research perspectives, it would be very useful to include the investigation of other species belonging to the same group, such as *G. angustum* and *G. occultum*. The new *Achnanthidium caravelense* is also characterized by a set of distinct morphological but also ecological features that separate it well from all other similar *Achnanthidium* species and it is widely distributed in Portuguese rivers. There is therefore a rather high probability that this species also occurs commonly in other European regions, in rivers with suitable conditions and has not yet been recorded due to probable misidentifications with *Achnanthidium eutrophilum* or *A. minutissimum*.

In addition, this study confirms that biological methods based on epilithic littoral diatoms and on the application of diatom indices (SPI) can be used for the assessment of the ecological status of reservoirs in Portugal in accordance with the requirements of the Water Framework Directive. Although our results demonstrate the value of littoral epilithic diatoms in the assessment of ecological status of reservoirs, it must still be stated that the knowledge about the species autoecology must be improved, since there is a lack of ecological information about several species characteristic of the hydromorphological types, such as *Achnanthidium catenatum*, *A. subhudsonis*, *Aulacoseira tenella*, *Discostella stelligera, Gomphonema pumilum* complex and *Tabellaria pseudoflocculosa*.

Further ecological studies are recommended in order to better characterize the species autecology, including populations from other regions. Moreover, the ecological preferences presented in this research should be compared with other regions in order to verify if there are differences and to improve their precision for the use in the indices calculation and to adapt their use for the ecological status assessment.